ELEKTOR
BOOK
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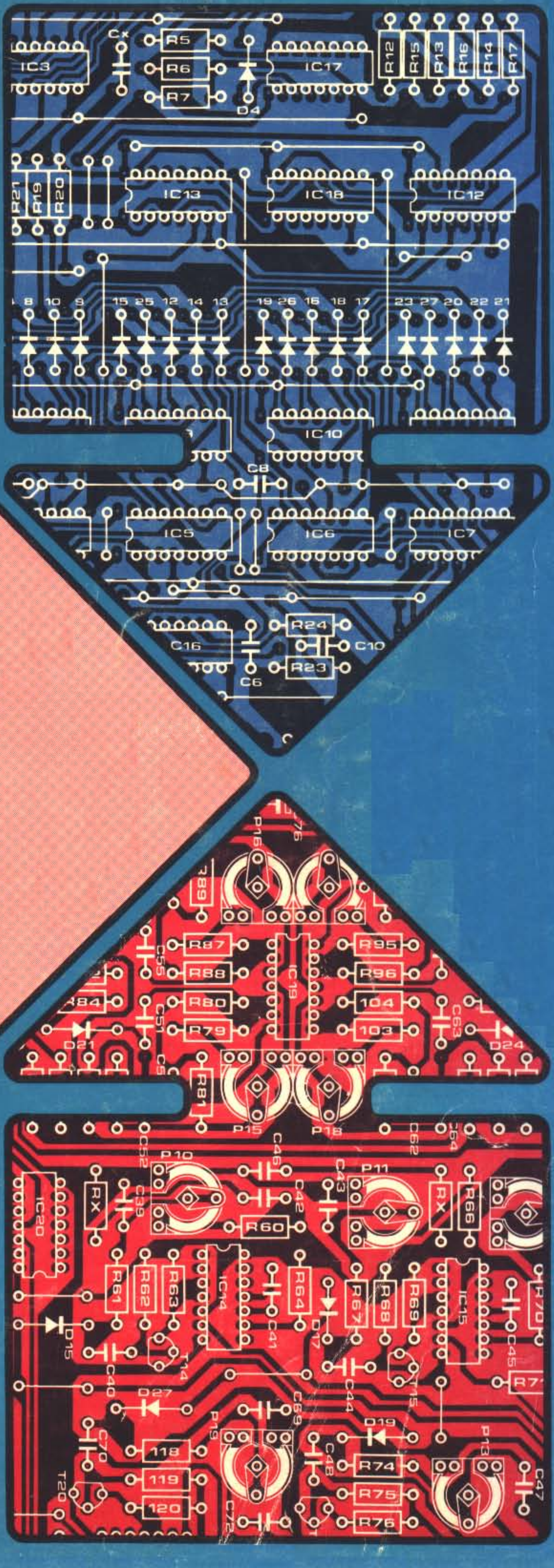

A selection of some of the
most interesting construction
projects in volume 1 (1975)
of ELEKTOR magazine.

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versatile digital clock

'One-chip' digital clocks, such as the MM5314 are excellent for simple time-keeping, however, they are not ideal for driving external devices such as time signals, calendars, etc. This is where this 'conventional' clock design can really be useful. This clock uses standard TTL IC's, has a BCD-coded time output, as well as pulse train outputs giving repetition rates varying from one per second to one per day. Several external devices that can be used with this clock are described further on ('Clamant clock' and 'calendar').

Elsewhere in this book there is a design for a 'one-chip' digital clock, with both mains and crystal reference frequencies. Whilst ICs such as the MM5314 are excellent for simple timekeeping, they have certain disadvantages. Since the output to the display is multiplexed the time output of the clock is not easily accessible in a parallel form. This means that the clock is unsuitable for driving time-controlled devices such as alarms, calendars, central heating programming, automatic recording of radio programmes or other systems. The clock described in this article is based on TTL circuitry and is eminently suitable for control systems. The time is available as a BCD coded output, and clock pulse trains with rates varying from one a second to one a day are obtainable. Many constructors will probably have some of the ICs in their 'junk box'.

The complete circuit of the clock (excluding power supply) is given in figure 1. The basic operation is quite simple. With all the switches in the positions shown the clock runs normally. The 50 Hz input is rectified by D1, clamped to 4.7 V by D2 and then fed into the NAND Schmitt trigger ST1. A 50 Hz square wave suitable for driving TTL appears at the output of ST1 and is fed to IC10 which is connected as a divide-by-five counter. Asymmetric 10 Hz pulses are available at the 'D' output of IC10. These pulses are fed to IC9, which is connected as a divide-by-10 counter. A symmetrical 1 Hz square wave is available at output 'A' of this IC.

The 1 Hz pulses are fed to IC6, which is connected as a BCD decade counter. This counts seconds from 0 to 10 and the BCD output may be decoded for display using a 7447. The 'D' output of IC6 produces one pulse every ten seconds, and this is fed to IC5, which is connected as a divide-by-6 counter. This counts tens of seconds from 0 to 6. When the tens of seconds count reaches 6 (i.e. the seconds display changes from 59 to 60) the BCD output of IC5 is 0110, that is to say the 'B' and 'C' outputs of the IC are both '1'. These outputs are connected to the Reset 0 inputs, so that when the count reaches 6 IC5 is reset instantaneously, and the 6 display is never seen.

One pulse per minute is obtained from the 'C' output of IC5, and this is fed through N2 and N1 to IC4, which is again connected as a BCD decade counter.

The time-setting circuits around N1 and N2 will be discussed later.

Like IC5, IC3 is connected as a divide-by-6 counter, so that it counts tens of minutes.

Counting of the hours is slightly more complicated. Since the clock is a 24 hour design, the hours counter (IC2) must count up to 10 twice, then reset at 4 on the third count sequence (i.e. when the hours count reaches 24). Since the tens of hours counter only counts to 2 a counter is made up from two JK flipflops (7473) instead of using a 7490. Resetting is accomplished as follows: During the first 0-10 count of IC2 the Q outputs of FF1 and FF2 are low. When the 'D' output of IC2 goes low on the tenth count the Q output of FF1 goes high. At the end of the second count sequence the Q output of FF1 goes low and the Q output of FF2 goes high. The Q output of FF2 and the 'C' output of IC2 are connected to the Reset 0 inputs of IC2, so that when IC2 reaches 4 in its third count sequence it is reset. However FF2 cannot similarly be reset as it has no gating on the clear input. This difficulty is overcome by feeding the 'B' output of IC2 to the clear input of FF2 via C1 and R3. On count 4 of IC2 the 'B' output goes low, feeding a momentary reset pulse to FF2. Of course this occurs at count 8 also, and during the first and second count sequences. However, it is only during the third count sequence that the Q output of FF1 is high anyway, so these earlier reset pulses do not matter, since the flipflop is reset already.

The capacitive coupling (C1, R3) is necessary to ensure that only a short reset pulse is provided. If direct coupling were used then the clear input would be held low on count 10 during the second count sequence, and the Q output of FF2 could not go high.

Provision of 'tick'

It will be noted that IC9 is connected differently from the other divide-by-10 counters (IC2, IC4 and IC6). This is because a BCD output is required from the other counters. IC9 is connected to give a symmetrical square-wave output, as a convenient simulated 'tick', and this happens to sound better with a 1:1 mark-space ratio.

Time-setting

Three time-setting switches are provided. Two to make the clock advance at a fast rate, and one to stop the clock. This is useful because the clock can be set to a particular time, stopped, then the stop button can be released exactly on the time signal from radio or telephone. It is also handy if the clock is accidentally advanced too far as it saves going all the way 'round the dial'. Gating for the time-setting is provided by a 7400 (IC7) plus the spare half of the 7413 Schmitt trigger (½IC8).

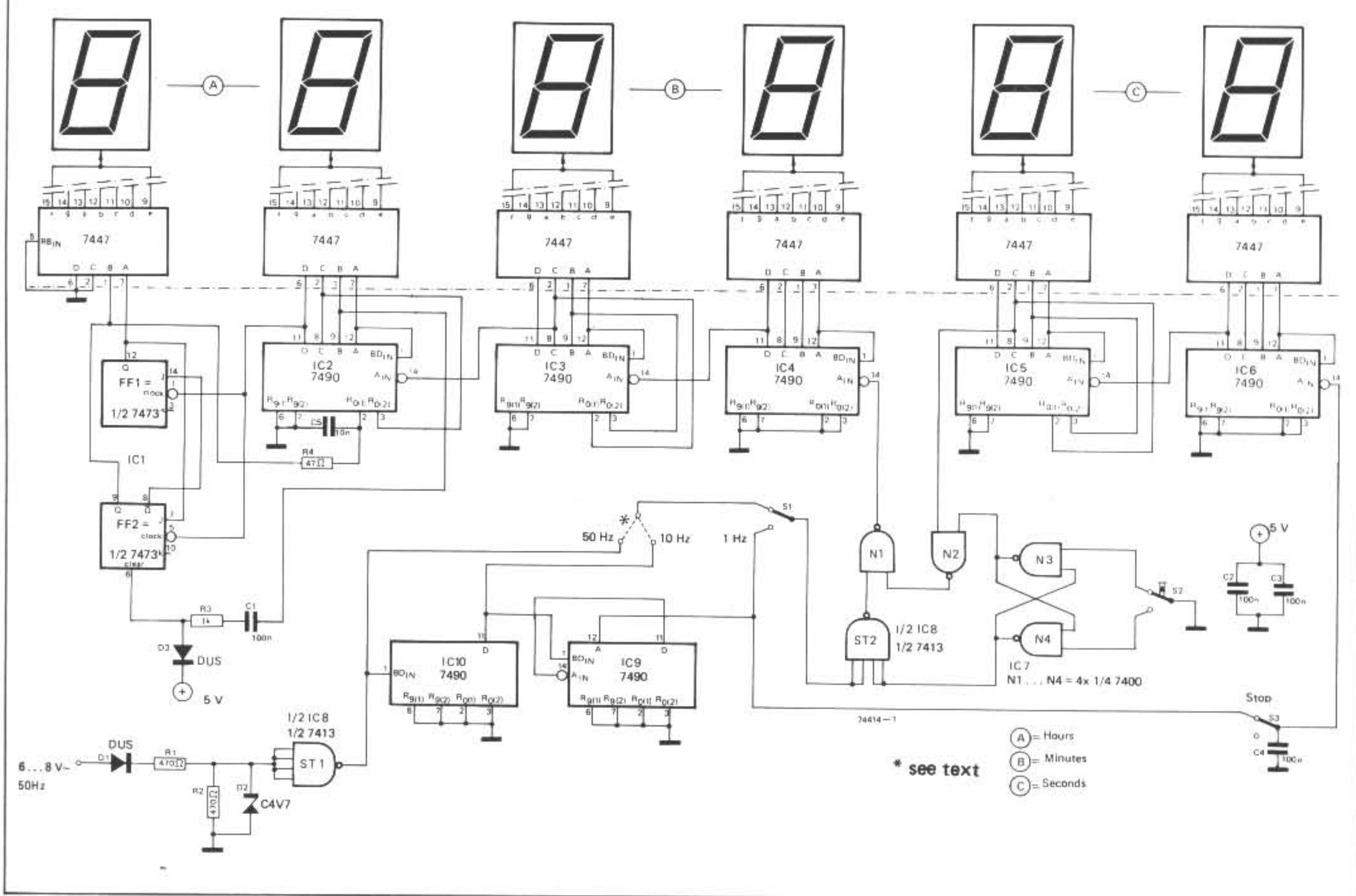
The operation is as follows: when S2 is in the position shown in figure 2a the set-reset flipflop N3/N4 is reset, so the output of N3 is high and the output of N4 is low. This means that the output of ST2 is high. Pulses from output 'C' of

Figure 1. Circuit diagram of the clock. The printed circuit board does not include the display and its associated decoder/drivers.

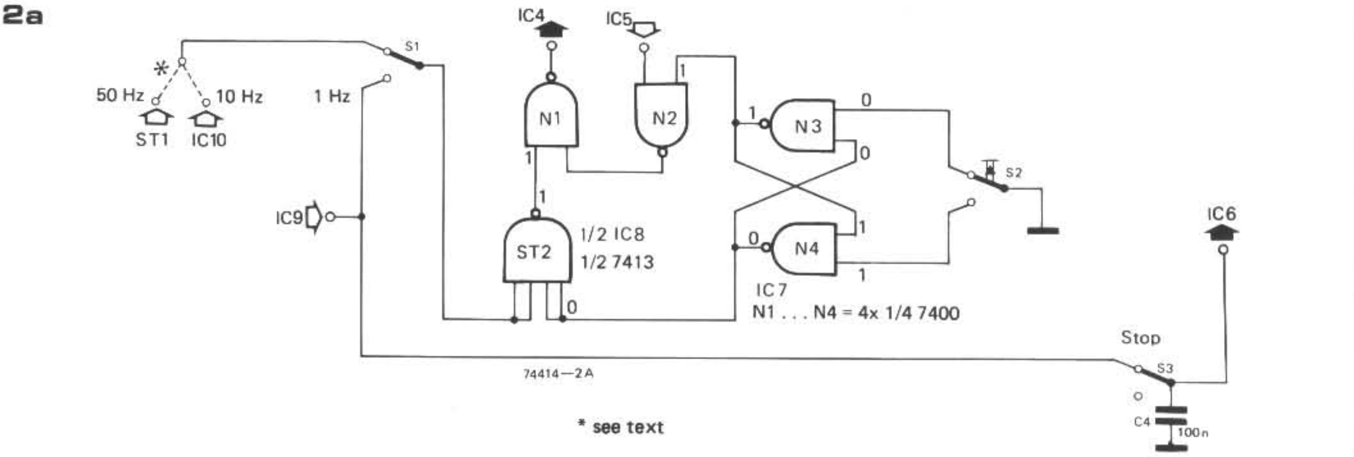
Figure 2a. Logic levels at NAND gates for normal timekeeping.

Figure 2b. Logic levels at NAND gates for time-setting.

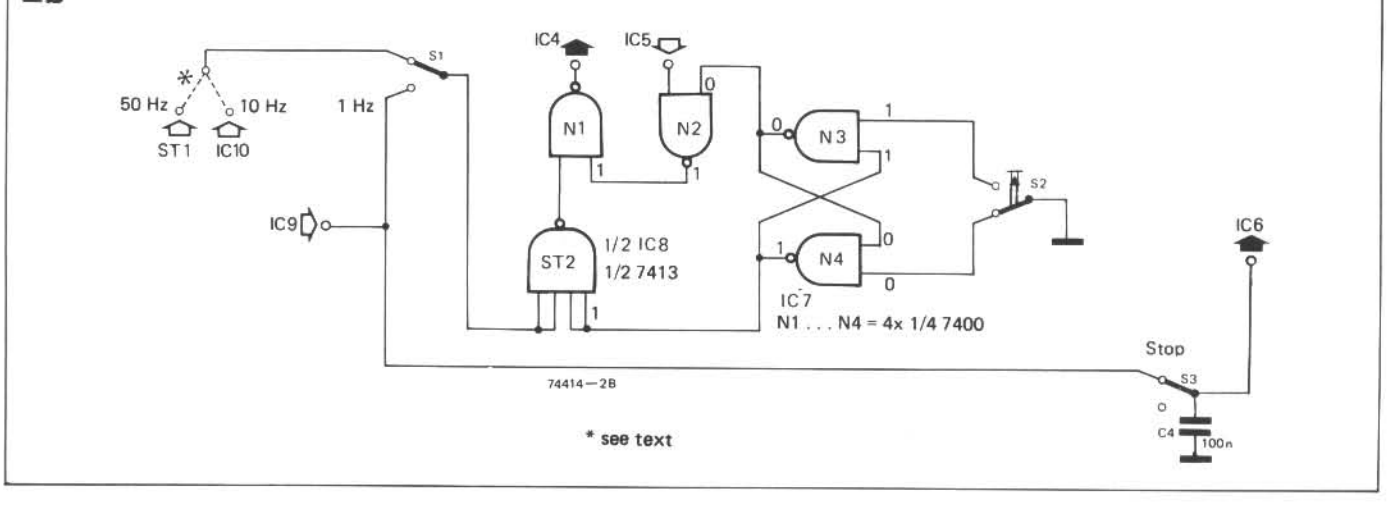
1


A
B
C
7447
IC1
FF1 = 1/2 7473
FF2 = 1/2 7473
IC2 7490
IC3 7490
IC4 7490
IC5 7490
IC6 7490
IC9 7490
IC10 7490
C5 10n
R4 47Ω
R3 1k
C1 100n
D3 DUS
5 V
S1
50 Hz
10 Hz
1 Hz
*
N1
N2
N3
N4
S2
ST2
1/2 IC8 1/2 7413
IC7 N1 . . . N4 = 4x 1/4 7400
+5 V
C2 100n
C3 100n
Stop
S3
C4 100n
74414-1
1/2 IC8 1/2 7413
ST1
6 . . . 8 V~ 50Hz
DUS D1
R1 470Ω
R2 470Ω
D2 C4V7
* see text
A = Hours
B = Minutes
C = Seconds

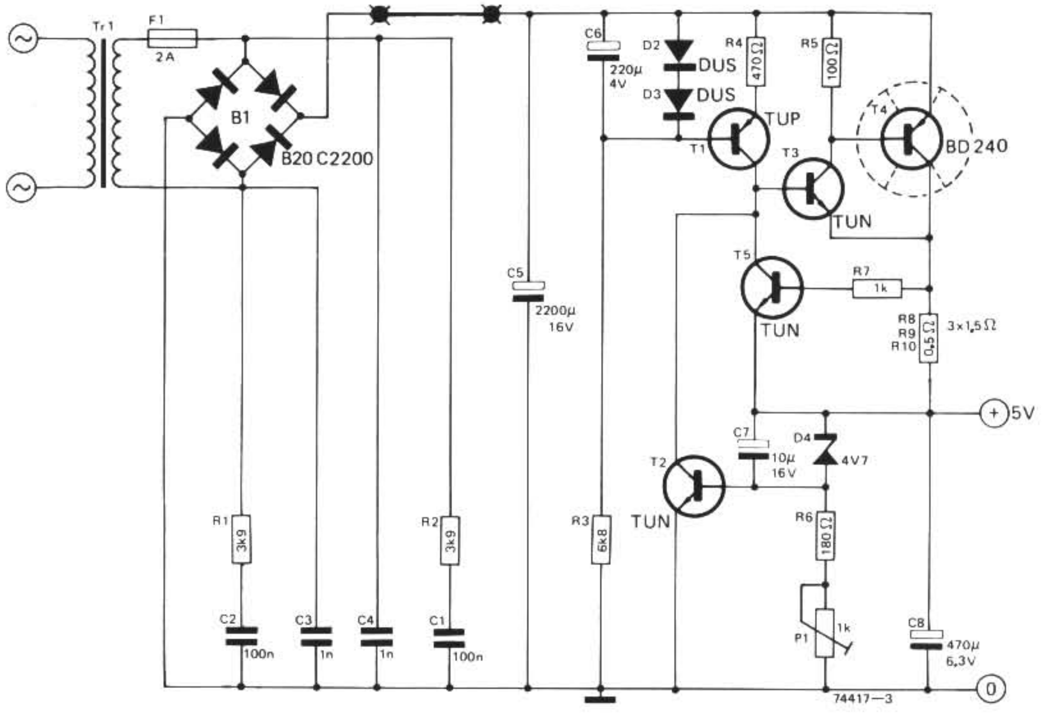
2a


S1
*
50 Hz
10 Hz
ST1
IC10
1 Hz
IC4
IC5
N1
N2
N3
N4
S2
IC9
ST2
1/2 IC8 1/2 7413
IC7 N1 . . . N4 = 4x 1/4 7400
IC6
Stop
S3
C4 100n
74414-2A
* see text

2b


S1
*
50 Hz
10 Hz
ST1
IC10
1 Hz
IC4
IC5
N1
N2
N3
N4
S2
IC9
ST2
1/2 IC8 1/2 7413
IC7 N1 . . . N4 = 4x 1/4 7400
IC6
Stop
S3
C4 100n
74414-2B
* see text

3



Parts list

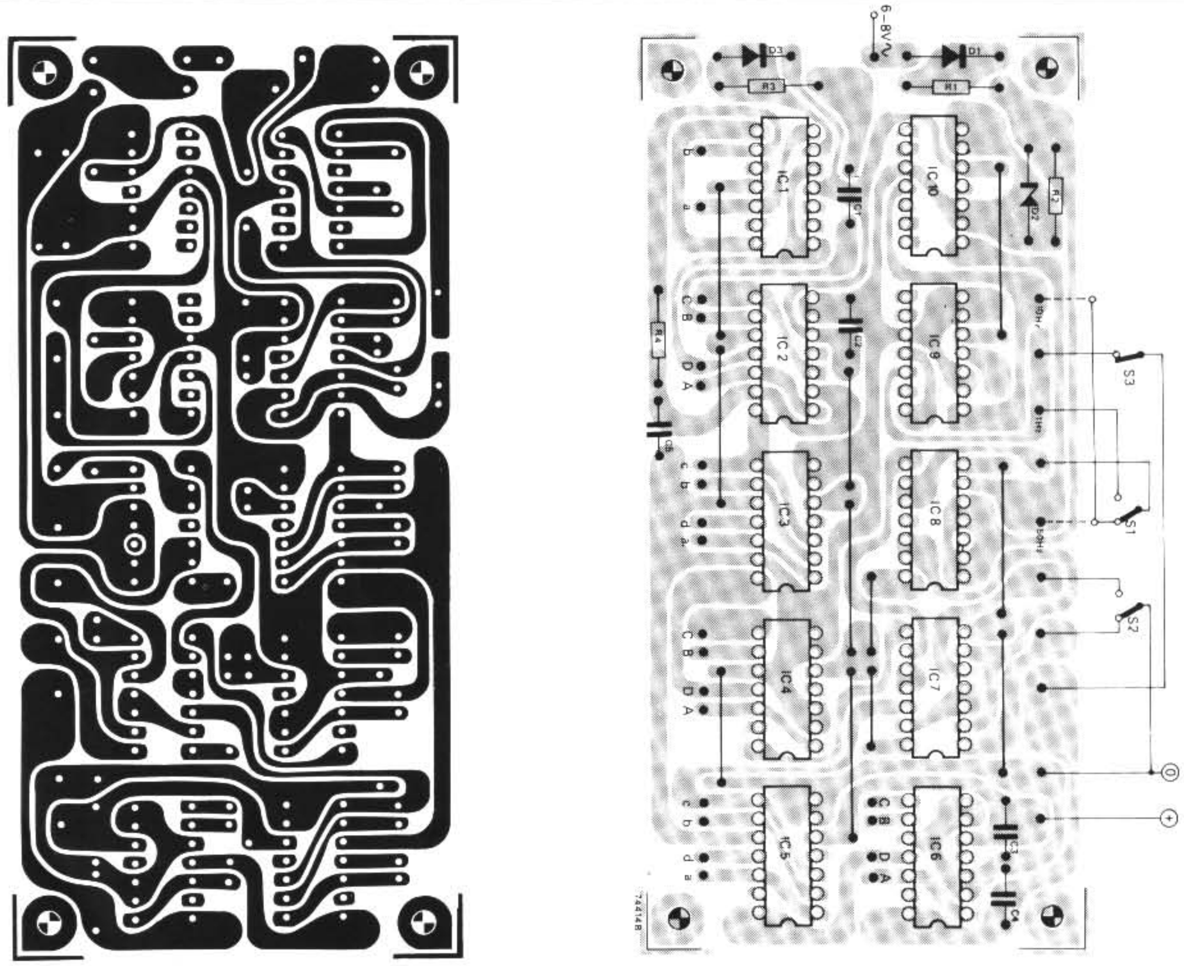
Resistors:
R1,R2 = 470 Ω
R3 = 1 k
R4 = 47 Ω

Capacitors:
C1,C2,C3,C4 = 100 n
C5 = 10 n

Semiconductors:
IC1 = 7473
IC2 ... IC6,IC9,IC10 = 7490
IC7 = 7400
IC8 = 7413
D1,D3 = DUS
D2 = Zener 4V7

Switches:
S1 = Single-pole, 2-way
S2 = Single-pole, 2-way, push-button operated
S3 = Single-pole on-off

4



IC5 are thus transferred through N2 and N1. When S2 is changed over (figure 2b) the flipflop is set. The output of N3 is low and the output of N4 is high. The output of N2 therefore goes high. 1 Hz or 10 Hz pulses (depending on position of S1) are now transferred through ST2 and N1 to the input of IC4. The clock will therefore count at the rate of one minute per second or 10 minutes per second. As an alternative to the 10 Hz rate, 50 Hz pulses may be used. This rate is useful only for setting the hours rapidly.

The flipflop is necessary to suppress contact bounce on S2. The flipflop is set (or reset) when the switch initially makes contact on being changed over. Subsequent switch bounce will not affect the state of the flipflop.

When S3 is changed over the 1 Hz drive is disconnected from IC6 so the clock stops. The position of S3 during time-setting with S2 is unimportant.

Power Supply

The clock requires a supply of about 1 A at 5 V. As transient interference on the mains supply could interfere with the timekeeping of the clock a stable, well-filtered mains supply is essential. The circuit of figure 3 is recommended, as this can deliver up to 2 A and is well stabilised. The 50 Hz drive for the clock can be derived from either side of the transformer secondary winding.

Construction

The p.c. board and layout for the clock are given in figure 4, and the assembly requires little comment. The BCD outputs of the counters are brought out to the edge of the board. Display decoding is not provided on the board. Suitable decoder and display boards are the 'Universal Display' (see following pages). If zero suppression on the tens of hours display is required pin 5 of the 7447 should be grounded.

The layout and p.c. board of the power supply are given in figure 5. The output voltage of the supply should be set to 5 V before connecting to the clock.

For 60 Hz operation, see the following page.

For use with crystal time base, see 'Universal time base'.

Table 1

COUNT	INPUTS D	C	B	A
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

Parts list

Resistors:
R1,R2 = 3k9
R3 = 6k8
R4 = 470 Ω
R5 = 100 Ω
R6 = 180 Ω
R7 = 1 k
R8,R9,R10 = 1.5 Ω
P1 = 1 k, preset

Capacitors:
C1,C2 = 100 n
C3,C4 = 1 n
C5 = 2200 μ/16 V
C6 = 220 μ/4 V
C7 = 10 μ/16 V
C8 = 470 μ/6.3 V

Semiconductors:
B1 = Bridge rectifier, e.g. B20C2200
D1 = omitted
D2,D3 = DUS
D4 = zener 4.7 V, 400 mW
T1 = TUP
T2,T3,T5 = TUN
T4 = BD240 or equ.

Sundries:
F1 = 2 A delay-action fuse
Tr1 = transformer, 8 V/2 A

Table 2

Clock Pulse Number	FF1 Input J1 (14) connected to $\overline{Q}2$	FF1 Output Q1 (12) BCD Code A	FF2 Input J2 (7) connected to Q1	FF2 Outputs Q2 (9) BCD Code B	FF2 Outputs $\overline{Q}2$ (8)	LED display
	1	0	0	0	1	0
1	1	1	1	0	1	1
2	0	0	0	1	0	2
3	1	0	0	0	1	0

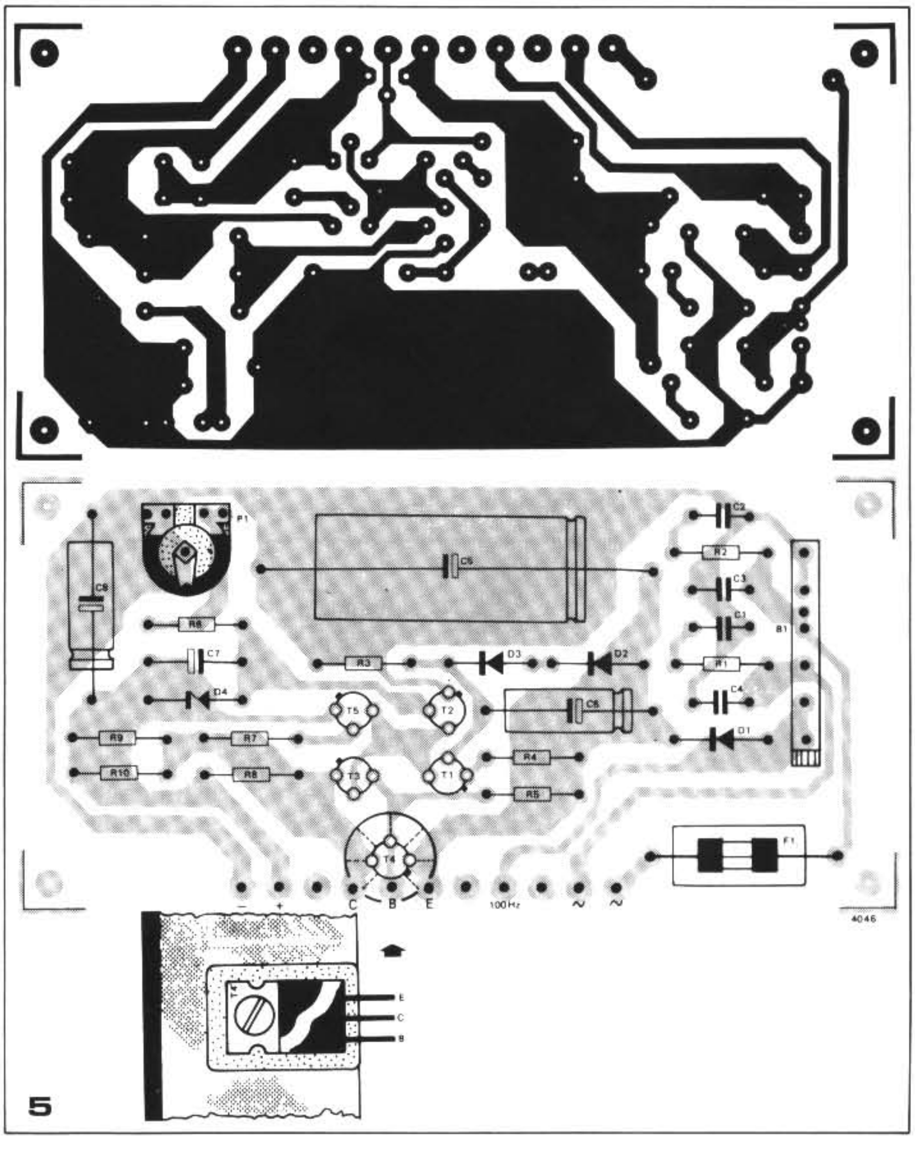
Table 1. BCD code.

Table 2. Truth table for IC1 (7473 connected as 1:3 divider).

Figure 3. Circuit of 5-V stabilised power supply.

Figure 4. Printed circuit and component layout of the clock.

Figure 5. Printed circuit and component layout of the 5-V stabilised power supply.



universal display

It is frequently necessary to have available a numeric display for many projects such as frequency counters, digital voltmeters etc. It is a tedious and untidy business to build up such displays on matrix board, so Elektor have designed a universal display which should satisfy the requirements of most enthusiasts. The display may be used with seven-segment LED indicators.

The universal display is modular in construction and its basic form consists of a board to accomodate two displays and their associated decoders. The system may be extended to any number of digits and decade counter/latch boards may also be added.

The universal display uses the popular 7447 decoder. The display format of this decoder is given in figure 1. However, for digits 6 and 9 the improved format described in Elektor 2, p. 258, is employed. This is shown in figure 2. The basic configuration of the decoder with the additional transistors is shown in figure 3 and the complete circuit of a display module for use with LED displays is given in figure 4.

Construction

Double-sided boards are employed in the construction of the display module and it may be seen from figures 5 and 6 that components are mounted on both sides of the board. It should be emphasised here that great care is required in the assembly of these boards due to the degree of miniaturisation involved. The soldering iron must have an extremely fine tip and soldering must be done extremely quickly to avoid peeling the fine track from the board. The boards available from Elektor employ plated- through holes, so that it is unnecessary to solder to component leads on both sides of the board. Simply solder on the opposite side of the board to that on which the component is mounted.

1

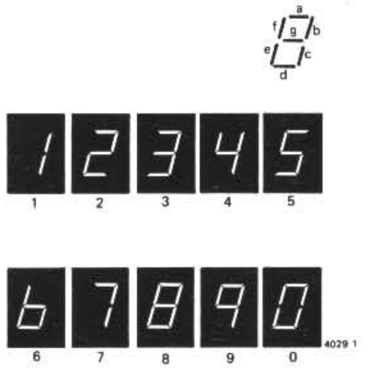


Figure 1. The display format produced by the 7447 decoder.

Figure 2. The improved presentation of the digits 6 and 9 as used in the universal display.

Figure 3. The circuit used with the 7447 to achieve the improved 6 and 9 display.

Figure 4. Circuit of the LED version of the universal display. Note that the decimal point series resistor has a higher value than the segment resistors to achieve the same luminous intensity.

Figures 5 and 6. The p.c. board and layout for the LED display. The track shown in feint in the component layouts is the side of the board on which the components are mounted, i.e. the components are mounted directly on top of the track shown. Figure 5 shows the components on the back of the board, and figure 6 shows the display side. (EPS4029-2).

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versatile digital clock

60 Hz operation

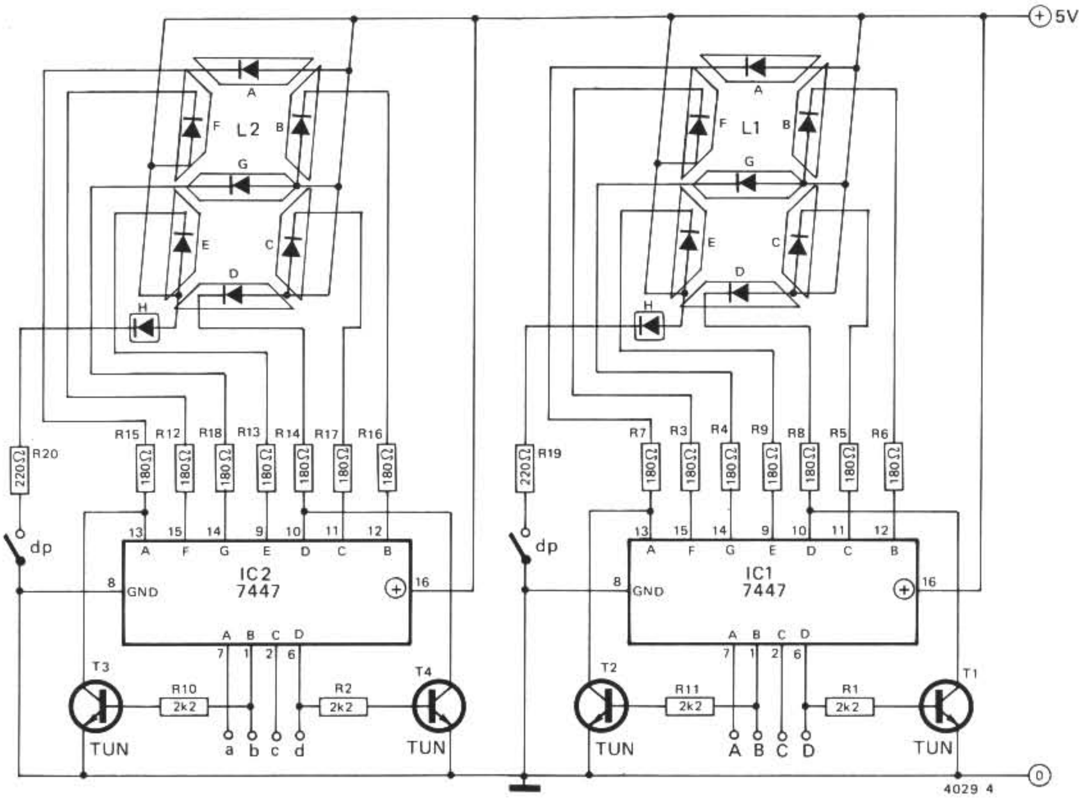
The versatile digital clock can be used in countries that use 60 Hz mains by making a few simple modifications.

First: break the circuit path on the p.c.b. between pin 11 of IC10 and pin 1 of IC9.

Then: connect a jumper wire between pin 8 of IC10 and pin 1 of IC9.

Finally, use a 7492 for IC10.

4



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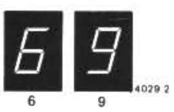

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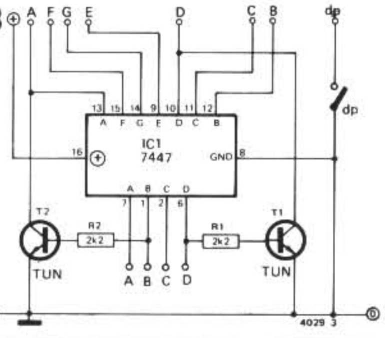
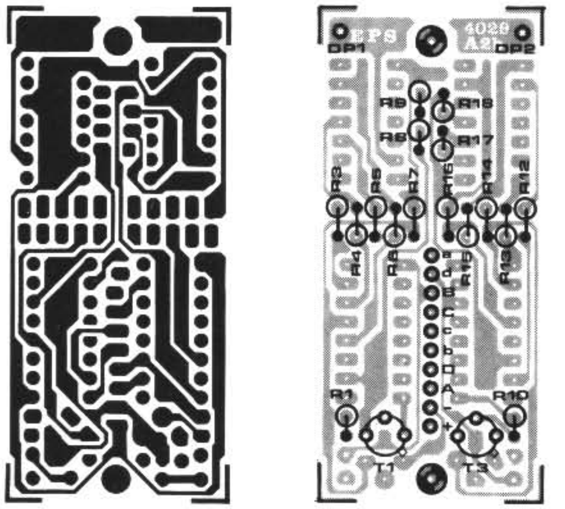


Components list for figure 4:

Resistors:
R1,R2,R10,R11 = 2k2
R3 to R9, R12 to R18 = 180 Ω

Semiconductors:
T1 to T4 = TUN
IC1,IC2 = 7447
L1,L2 = e.g. H.P.5082-7730 or
7750, Opcoa SLA 1, T.I.
Til 302, Data Lit DL 707.

5



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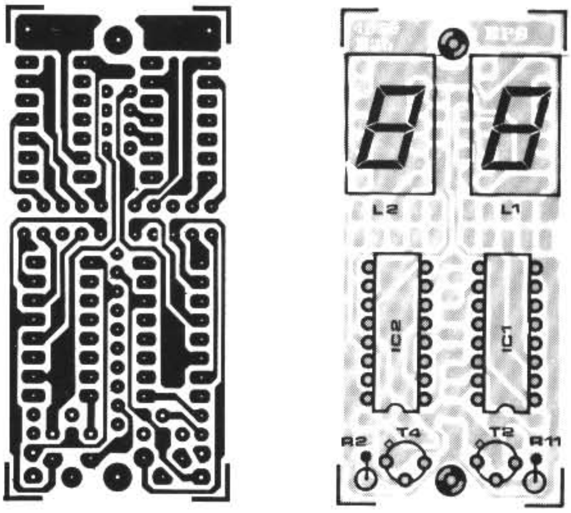


sensitive coil-less synchrodyne receiver for MW and LW

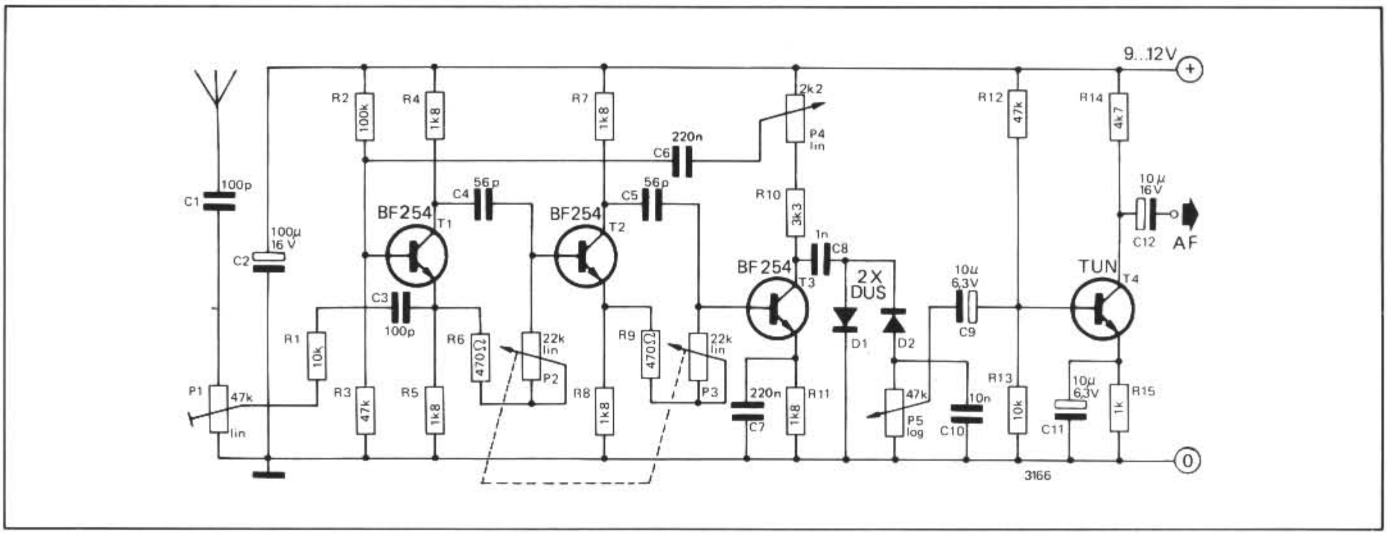
This little receiver tunes the medium and long wave-ranges. It operates without any coils by employing a synchronised oscillator.

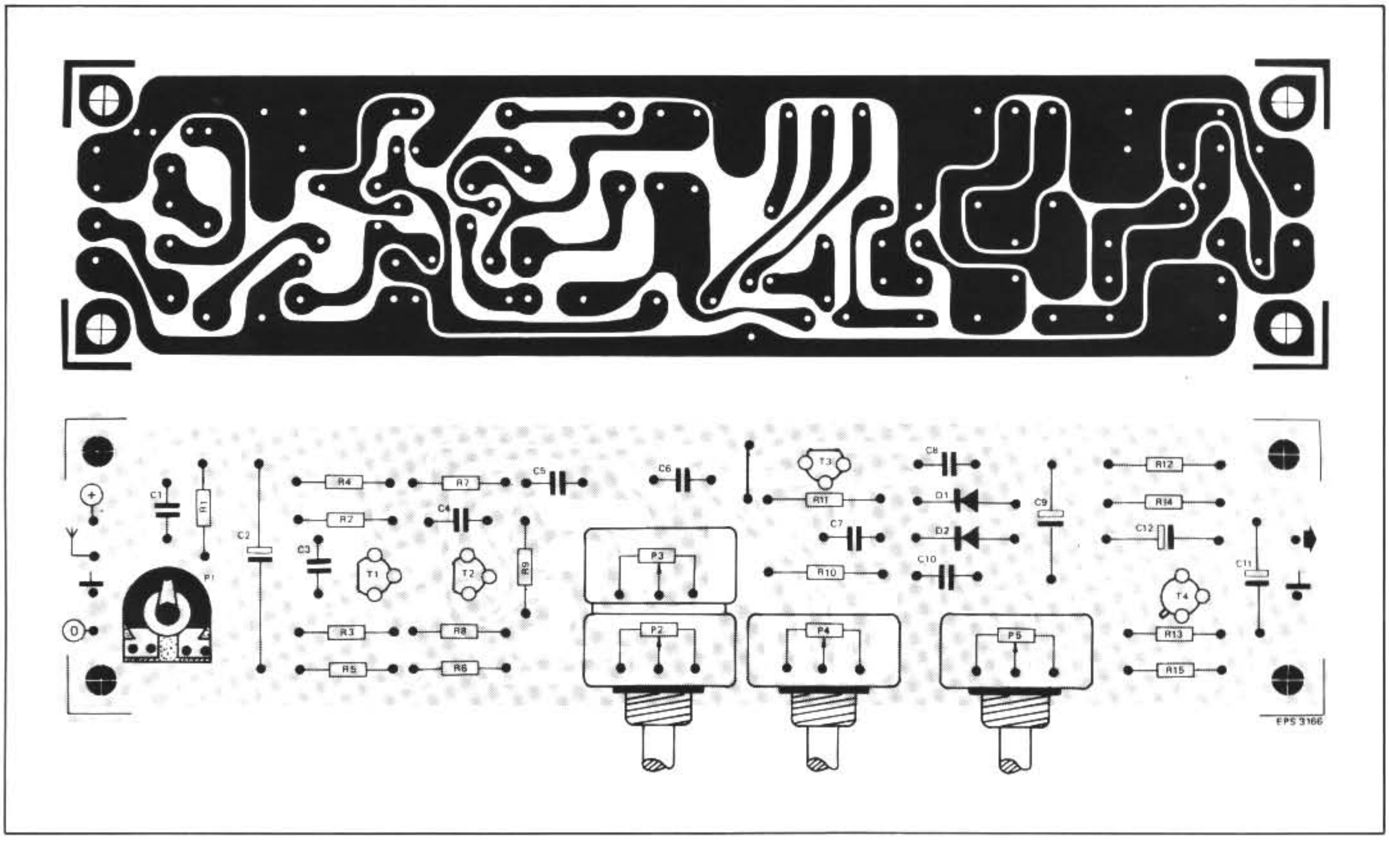
When the oscillator is barely able to maintain oscillations, it will synchronise to an incoming signal frequency close to its free-running value. The amplitude of the oscillation follows, more or less linearly, the modulation of the incoming signal. The circuit can synchronise itself to a signal of some tens of microvolts, so that its effective sensitivity is very high.

P4 sets the level of oscillation; the stereo-ganged pair P2 and P3 form the 'tuning' control. Since this stereo-potentiometer covers a very wide range it may be necessary to add a 'fine' control consisting of a low-value stereo-potentiometer in series (typically 1 k or 500 ohm).

The modulated oscillator signal is passed to the amplifier stage with T4, via the full-wave 'detector' with D1 and D2. The output level is sufficiently high for driving most amplifiers.

A short aerial, such as a piece of wire, is enough to provide quite reasonable reception. If a good aerial is to be used, P1 can be inserted to prevent over-driving by too strong a signal.





mini hifi

In contrast to the now-prevalent 'multiwatt' systems currently on the market, a design is described for a Hi-Fi stereophonic amplifier of modest specification for the price-conscious constructor. The system is built from several units that are matched to one another, but this does not preclude their use with other equipment.

The block diagram of figure 1 shows how the units are connected together to form a complete stereo amplifier. The disc preamplifier is required only with a magnetic cartridge. It is followed by the control amplifier which incorporates balance, volume and tone controls. This stage will accept inputs from high level sources such as radio and tape.

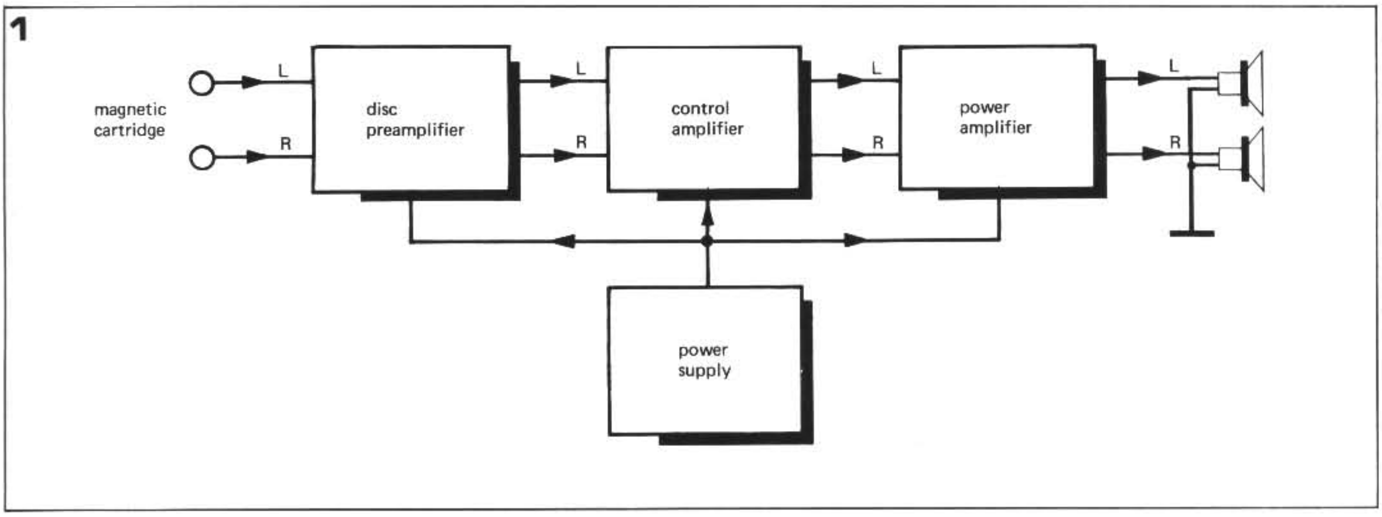
The control amplifier drives the power amplifier which will provide up to 3 watts per channel; this is sufficient for the average living room. A regulated power supply provides the H.T. for all three stages of the amplifier.

The disc preamplifier

The disc preamplifier, the circuit of which is given in figure 2 (one channel only shown), incorporates equalisation to correct the output of a magnetic cartridge according to the RIAA playback curve, and also amplifies the signal to a level sufficient to drive the control amplifier. It consists of a two-stage voltage amplifier, T4 and T5, with the RIAA feedback network R18, R19, C15 and C16 connected from the collector of T5 to the emitter of T4. DC feedback and biasing of T4 is provided by R15.

The disc preamplifier board should preferably be mounted inside the turntable itself as otherwise the capacitance of the screened lead between the cartridge and the disc preamplifier can form a resonant circuit with the self-inductance of the cartridge. If this resonance lies within the audio spectrum it may cause a peak in the frequency

1



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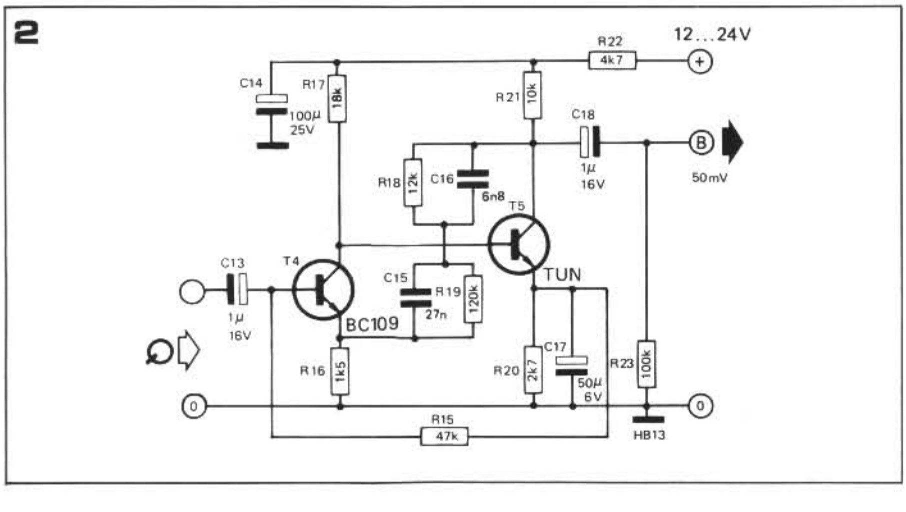
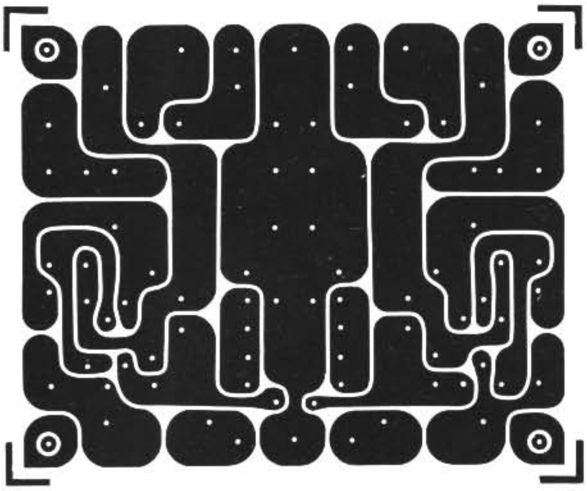


Figure 1. An economical Hi-Fi stereo amplifier built of four units. Each unit may also be used in conjunction with other equipment.

Figure 2. The circuit of the disc preamplifier. It is designed for use with magnetic cartridges and incorporates RIAA correction.

3



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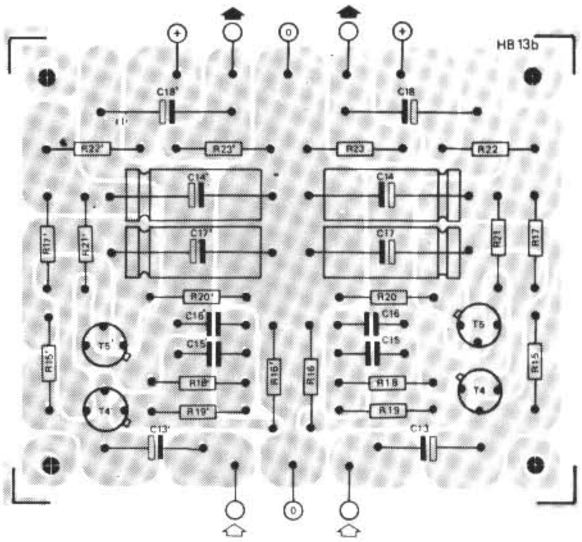

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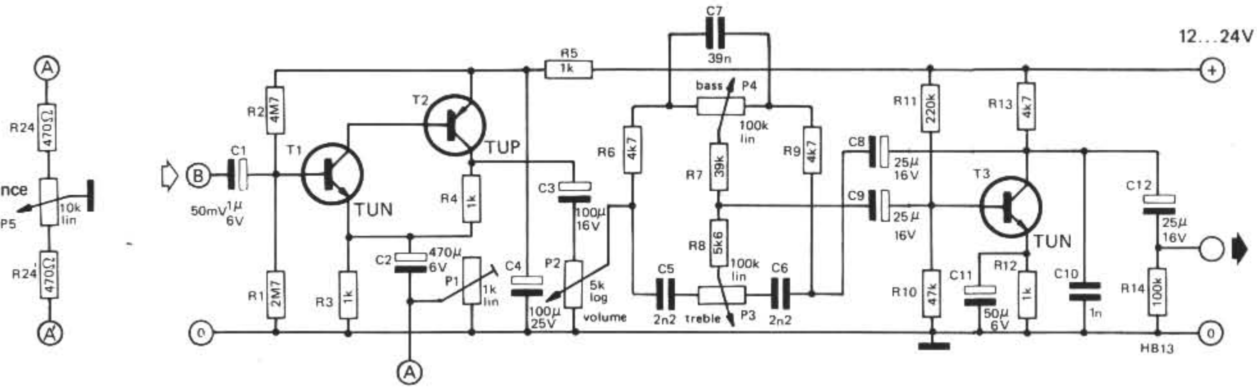


response. Of course some cartridge manufacturers quote a recommended load capacitance and if this is so their recommendations should be adhered to. Another good reason for mounting the disc preamplifier inside the turntable is to keep it away from the hum fields of the amplifier's mains transformer. Turntable motors usually have much less stray field then the average mains transformer!

The printed circuit board for the disc preamplifier is given in figure 3 and the associated component layout in figure 4. It can be seen that the layout for the two channels is symmetrical.

The control amplifier

The circuit of one channel of the control amplifier is given in figure 5. T1 and T2 form a voltage amplifier with a high input impedance and a low output impedance. Two versions of the power amplifier are described in the following section; a 12-volt version, to give 3 watts into 4 Ω and a 17-volt version, to give 3 watts into 8 Ω. Since the output voltage of the amplifier for 3 watts into 4 Ω is 3.5 V RMS, whereas for an 8 Ω load it is 4.9 V RMS, the 17-volt version of the power amplifier requires a larger input signal, since its gain is fixed. This is accomplished by varying the gain of the control amplifier by means of P1. P1 is also used to match the gains of the two channels so that channel balance is correct with the balance control central. With P1 set to 1 k the input sensitivity when used with the 12 volt version of amplifier is about 150 mV for 3 watts into 4 Ω.

P2 is the volume control and this is followed by a standard 'Baxandall' tone control circuit which gives a range of ±12 dB on both bass and treble. The balance potentiometer P5 completes the controls. C10 is a high-frequency bypass capacitor to avoid instability. The p.c. board and component layout of the control amplifier are given in figures 6 and 7.

The power amplifier

In the circuit of figure 8 T1 and T2 form a direct-coupled voltage amplifier which controls the bias of the quasi-complementary driver/output stage T3, T5 and T4, T6. R7 and R8 are chosen so that the output devices are either just biased on or just cut off depending on the gain of the devices used. C3, C5 and R3 help to maintain stability. The input sensitivity of the amplifier is about 400 mV for 12 volt operation with a 4 Ω load, and 600 mV for 17 volt operation with an 8 Ω load. The gain

Figure 3. The layout of the p.c. board for the disc preamplifier shows the symmetrical arrangement of the two channels. (EPS HB14).

Figure 4. The component layout for the disc preamplifier board of figure 3.

Figure 5. The circuit of one channel of the control amplifier.

Figure 6. The printed circuit for the control amplifier. (EPS HB13).

Figure 7. The component layout of the control amplifier.

Parts list for figures 2 and 4:

Resistors:
R15 = 47 k
R16 = 1k5
R17 = 18 k
R18 = 12 k
R19 = 120 k
R20 = 2k7
R21 = 10 k
R22 = 4k7
R23 = 100 k

Capacitors:
C13 = 1 µ, 6 V
C14 = 100 µ, 25 V
C15 = 27 n
C16 = 6n8
C17 = 50 µ, 6 V
C18 = 1 µ, 16 V

Semiconductors:
T4 = BC 109
T5 = TUN

Parts list for figures 5 and 7:

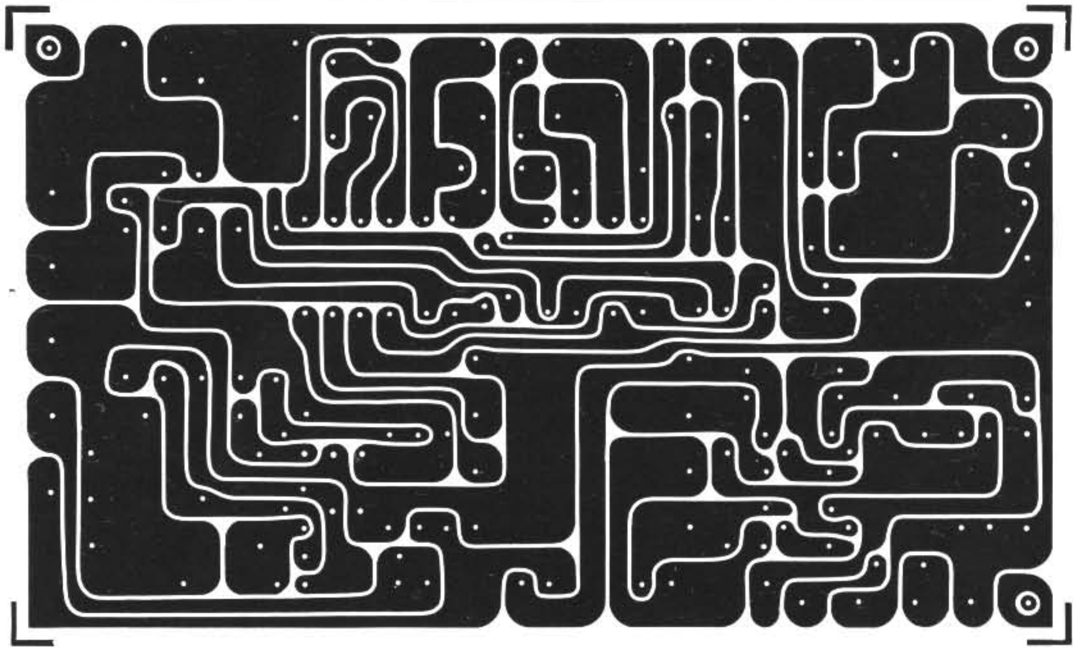
Resistors:
R1 = 2M7
R2 = 4M7
R3,R4,R5,R12 = 1 k
R6,R9,R13 = 4k7
R7 = 39 k
R8 = 5k6
R10 = 47 k
R11 = 220 k
R14 = 100 k
R24 = 470 Ω

Capacitors:
C1 = 1 µ, 6 V tantalum
C2 = 470 µ, 6 V
C3 = 100 µ, 16 V
C4 = 100 µ, 25 V
C5,C6 = 2n2
C7 = 39 n
C8,C9,C12 = 25 µ, 16 V
C10 = 1 n
C11 = 50 µ, 6 V

Semiconductors:
T1,T3 = TUN
T2 = TUP

Miscellaneous:
P1 = preset potentiometer 1 k lin.
P2 = potentiometer 4k7 log. stereo
P3,P4 = potentiometer 100 k lin. stereo
P5 = potentiometer 10 k lin.

6



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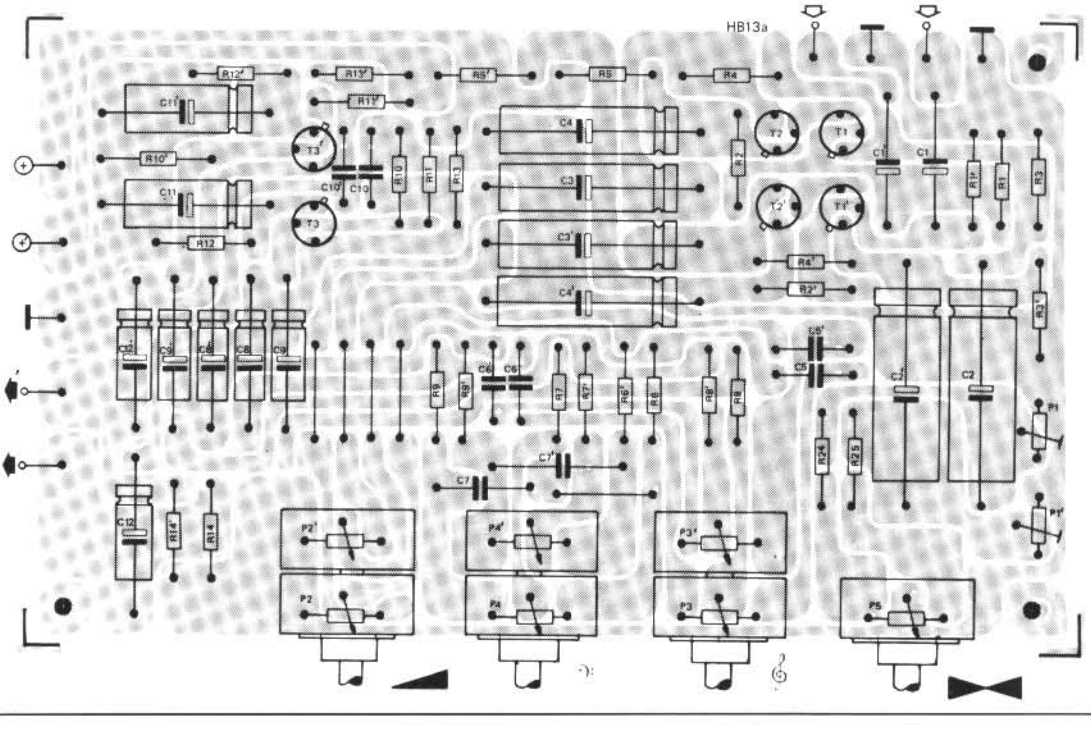

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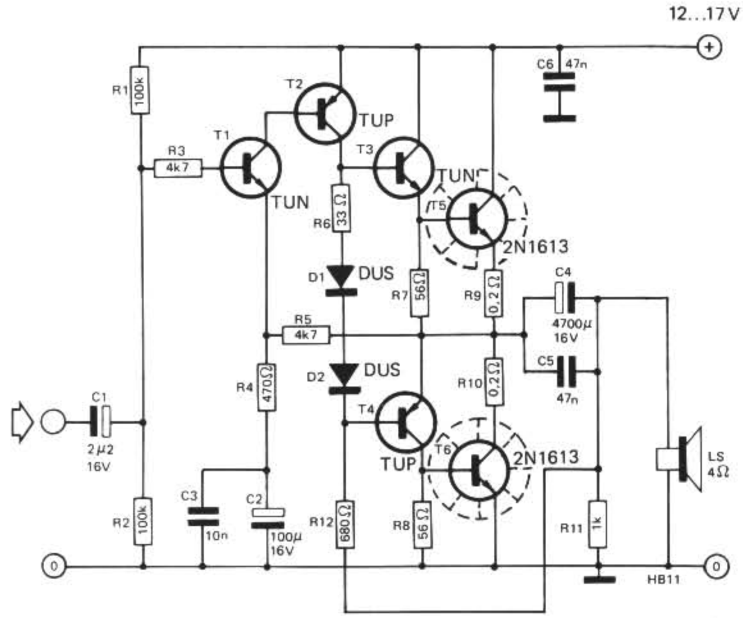

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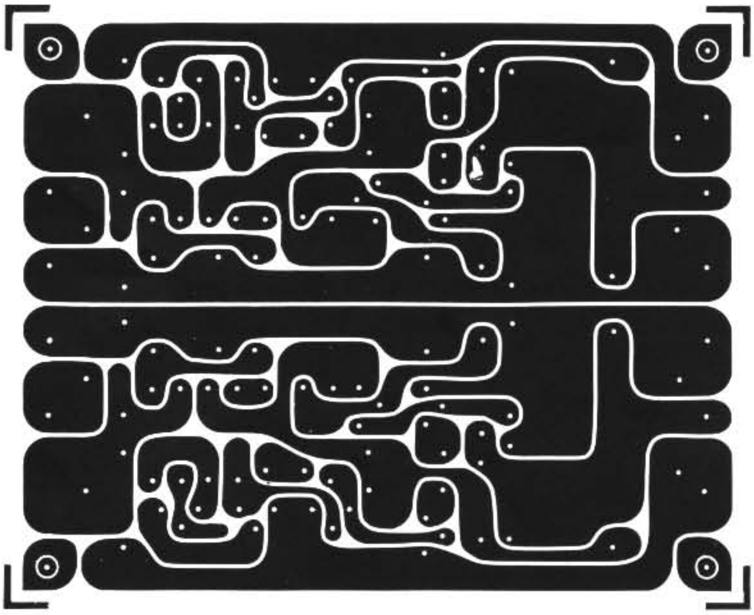

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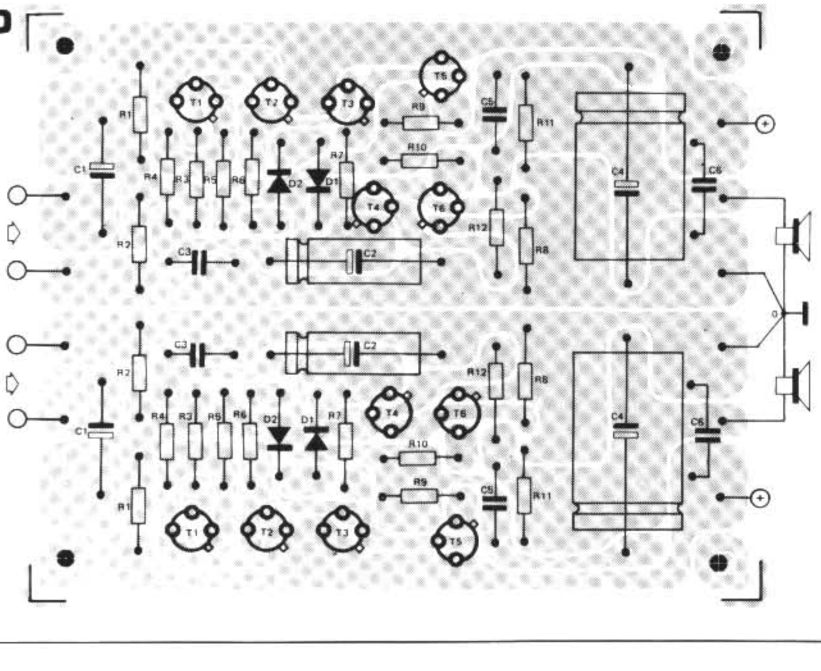


Figure 8. The output amplifier, which will deliver 3 watts into 4 Ω with a 12 volt supply and 3 watts into 8 Ω with a 17 volt supply. The different values for R12 and C4 are given in the table.

Figure 9. The printed circuit for the power amplifier is also symmetrical. It may be cut in half for mono applications if desired.

Figure 10. Component layout for the power amplifier p.c. board. (EPS HB11).

Figure 11. The circuit of the simple stabilised supply. The values of R1 and Z1 depend on the supply voltage required.

Figure 12. Board and component layout for the power supply. (EPS HB12).

Parts list for figures 8 and 10:

Resistors:
R1,R2 = 100 k
R3,R5 = 4k7
R4 = 470 Ω
R6 = 33 Ω
R7,R8 = 56 Ω
R9,R10 = 0,2 Ω
R11 = 1 k
R12 = see table

Capacitors:
C1 = 2,2 μ, 16 V
C2 = 100 μ, 16 V
C3 = 10 n
C4 = see table
C5,C6 = 47 n

Semiconductors:
T1,T3 = TUN
T2,T4 = TUP
T5,T6 = 2N1613
D1,D2 = DUS
2 TO5 heatsinks for T5 and T6

	12 V	17 V
R12	680 Ω	1 k
C4	4700 μ	2200 μ
LS	4 Ω	8 Ω

may be increased by reducing R4 but this is not recommended as instability may occur and in any case the overall gain of the system may be altered by adjusting P1 on the control amplifier board. The printed circuit for the power amplifier is given in figure 9 and the component layout in figure 10.

Supply

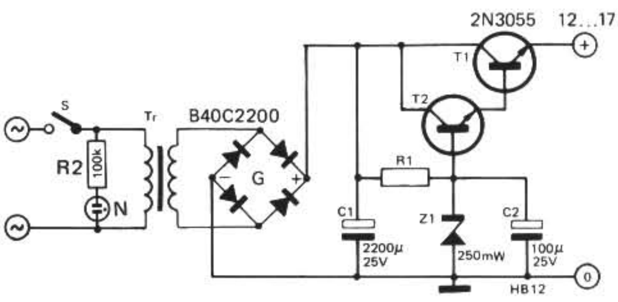
The regulated power supply is very simple, as can be seen from figure 11. T1 and T2 form a Darlington pair acting as a compound emitter-follower with a reference voltage provided by Z1. Z1 is chosen as a 13 or 18 volt zener for a 12 or 17 volt supply respectively. Since T2 dissipates only a small amount of power a heatsink is not required.
Figure 12 shows the board and component layout of the power supply. The component values for both versions are given in the table of figure 11.

Layout

The following layout precautions should be noted when assembling the completed board onto a chassis:

1. Loudspeaker common must be connected directly to the power supply common and should be kept well away from the boards.
2. Separate leads must be run from the supply to the supply points on each board.
3. Outputs of any board should be kept well away from inputs of other boards (except of course where the output of a stage is connected to the input of the succeeding stage).
4. Care should be taken to avoid earth loops. Each section of the amplifier should have only one connection to supply common.

11



Parts list for figures 11 and 12:

Resistor:
R1 = see table
R2 = 100 k

Capacitors:
C1 = 2200 μ, 25 V
C2 = 100 μ, 25 V

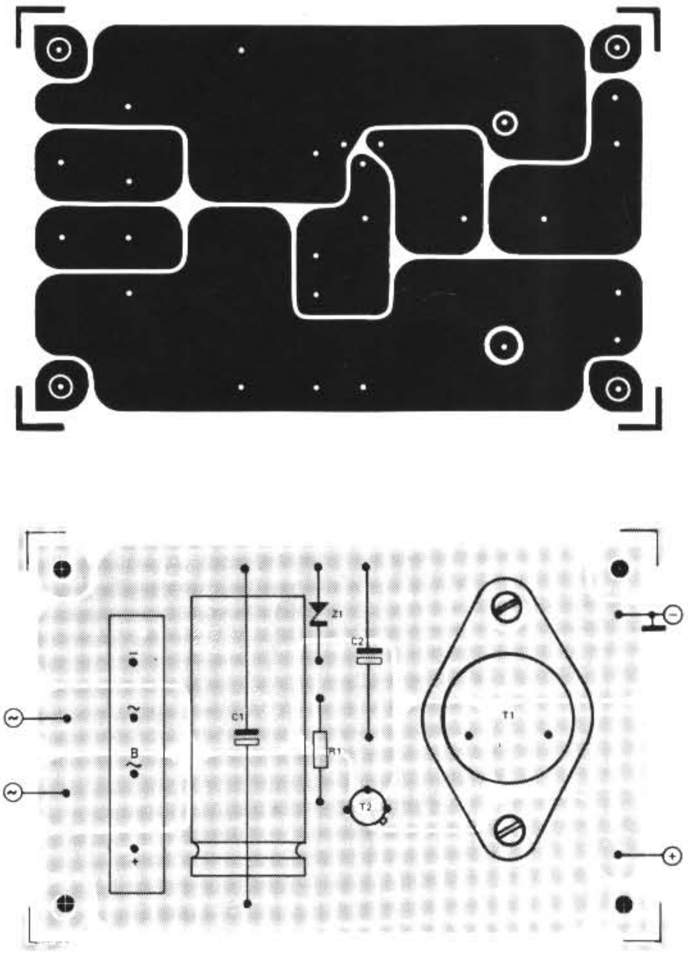
Semiconductors:
T1 = 2N3055
T2 = see table

Transformer:
Tr1 = 2 A sec. see table

Miscellaneous:
G = B40C2200 40 V 2.2 A bridge rec. or 4 x 1N4001
Z1 = zener diode, 250 mW, see table
N = neon
S = switch on/off

	12 V	17 V
R1	270 Ω	680 Ω
Z1	13 V	18 V
T2	TUN	BC 107
Tr	12 V~	18 V~

12



tup tun tester

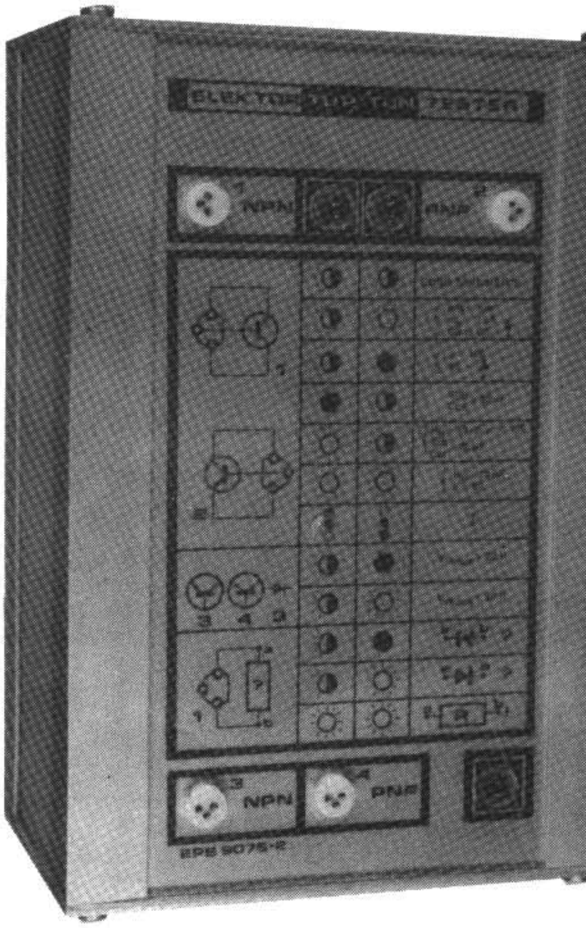
This tester gives an instant check of the 'general health' of a transistor, as well as its compliance with the minimum TUP or TUN specification, by the very simple procedure of plugging it into test sockets and interpreting the messages from two light-emitting diodes. It is also possible to check diodes for excessive capacity or leakage.

The principle of operation is simple and no preliminary calibration is needed – only the use of transistors and diodes known to be 'good' and resistors within the specified tolerance.

An astable multivibrator generates a square wave at a frequency of about 2 kHz, and this oscillation is turned on and off by another multivibrator at about 2 Hz. The collector-emitter path of the transistor under test (or the anode-cathode path of the diode) is connected in series with another transistor across the supply rails, and the intermittent 2 kHz square wave is fed in antiphase to the bases of each of the two transistors. Figure 1 shows a block diagram of the arrangement, from which a lot of information about the semiconductor under test can be deduced from the 'behaviour', voltage-wise, of the junction between the two semiconductors. This information can be displayed with the aid of only two light-emitting diodes (LEDs).

Circuit Description

Figure 2 shows the complete circuit, which has been divided into three sections to avoid confusion. Transistors T5 and T6 in figure 2a form an astable multivibrator which runs at about 2 kHz. T2 and T3 form another multivibrator which runs at a much lower speed, about 2 Hz, and turns the 'fast' (2 kHz) oscillator on and off through transistor T4, which also supplies a 2 Hz switching waveform, via connection 'Q', to the display section T7 ... T9 and LEDs 'A' and 'B' (figure 2c). A similar 2 Hz switching waveform, in antiphase to the one which appears at 'Q', is supplied to the display section by T1 via 'P'. As will be seen later, these switching waveforms are needed to enable an unambiguous display to be obtained from two LEDs only.



An optional third LED (shown in the circuit as LED 'C') can be connected in series with the 680 Ω resistor R9 between 'Q' and supply negative. This will give a partial test of the tester itself by blinking in step with the slow oscillator if this is functioning.

2 kHz square waves of equal amplitude and opposite polarity are produced intermittently at the collectors of T5 and T6. These two points, which drive the whole of the test circuitry, are marked 'X' and 'Y' respectively. When the fast oscillator is turned off, T5 is cut off and its collector ('X') is at its higher potential.

The left-hand half of figure 2b is the section in which PNP-transistors are tested. It has been shown that 2 kHz square waves of equal amplitude and opposite polarity are being injected intermittently at 'X' and 'Y'.

Display

Assume that a (good) PNP transistor is plugged in at the test point T_A in figure 2b. When the fast oscillator is off, 'X' is positive and 'Y' is negative. (The terms 'positive' and 'negative' are used to denote the higher and lower potentials taken up by various points in the circuit). Both the transistor T10 and the transistor T_A under test are therefore cut off, and the connection joining the collectors of T10 and T_A is floating. The diode D10 does not pass any current and the Darlington pair T11 and T12 is cut off. Figures 2b and 2c show that the collector of T12 is one of the points connected to the base of T9 (point A). When T12 is cut off, 'A' is positive and T9 is therefore also cut off. LED 'B', which is in the collector lead of T9, is therefore off, and the collector of T9 is negative.

To find what LED 'A' is doing, the other switching waveforms, derived from the slow oscillator via 'P' and 'Q', must now be examined. To switch the fast oscillator off, 'Q' must be negative; therefore 'P' is positive. T7 is connected to 'P', so T7 can conduct if its base receives a positive drive from the collector of T9 via R19.

In the situation now under consideration, however, the collector of T9 is negative and T7 does not pass current. T8 is also returned to the negative rail through LED 'A', but 'Q' is negative so LED 'A' stays off.

Recapping at this stage; with a good

transistor and when the fast oscillator is turned off, both LEDs are off.

It has been seen that the three points which determine the LED display are 'A', 'P' and 'Q'. The basic relationship is as follows:

1. When 'P' is positive (i.e. the fast oscillator is turned off), LED 'A' will light up if the base of NPN transistor T7 is driven positively from the collector of T9.
2. When 'Q' is positive (i.e. the fast oscillator is turned on), LED 'A' will light up if the base of PNP transistor T8 is driven negatively from the collector of T9.
3. LED 'B' lights up when the collector of T9 is positive, irrespective of whether 'P' or 'Q' is positive.
4. When 'A' is negative, the collector of T9 is positive.

   These relationships can be combined in a kind of truth table which will help in predicting the display for transistors or diodes in different states of health. They are also summarised, in a slightly different form, in figure 3a + b.

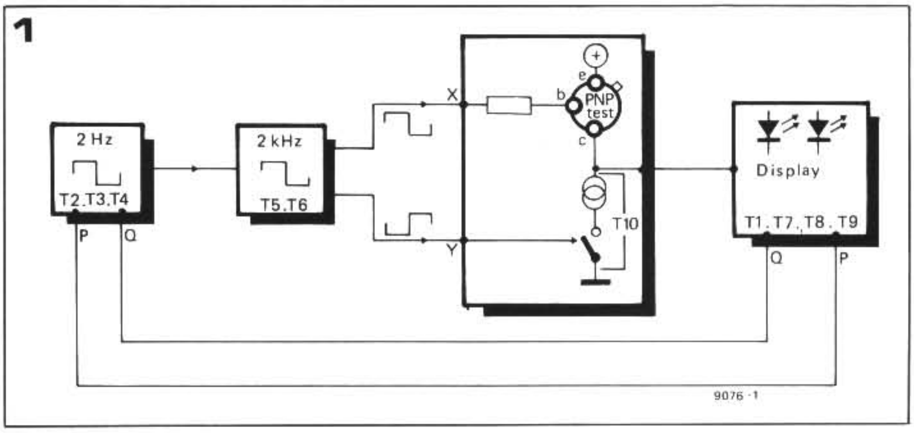
FAST OSCILLATOR TURNED	'A' SWINGS	LED A	LED B
Off	positive	Off	Off
Off	negative	On	On
On	positive	On	Off
On	negative	Off	On

What happens during the bursts when the fast oscillator is turned on?

'X' and 'Y' are being swung alternately positive and negative with opposite polarities at 2 kHz. When 'X' swings positive and 'Y' swings negative, the same reasoning which was applied to the situation when the fast oscillator is turned off will indicate that 'A' swings positive and LED 'B' is off. In this case, however, the fast oscillator is turned on ('Q' is therefore positive) and LED 'A' lights up.

When 'X' swings negative and 'Y' swings positive, it will be seen from figure 2b that both T10 and the transistor under test in T_A are turned on. The emitter of T_A is directly connected to supply positive, while the emitter of T10 is connected to supply negative through the 470 Ω resistor R28. If the current gain of T_A is high enough, the potential at the collector of T_A will move positively, D10 will conduct and the base of T11 will also move positively. (This will be discussed in more detail later.) The emitter of T12, the other transistor in the Darlington pair, is held by R30 and R31 at half the supply rail potential, so T12 is turned on; its collector potential (point 'A') swings negative and, as can be seen from the table, LED 'B' lights up and LED 'A' is off.

So the LED display while the fast oscillator is turned on and the transistor is a 'good' one is that 'A' and 'B' each come on during alternate half-cycles of the 2 kHz oscillation. Both LEDs therefore appear to be on during each 2 kHz burst, and it has already been seen that both are off while the fast oscillation is turned off.



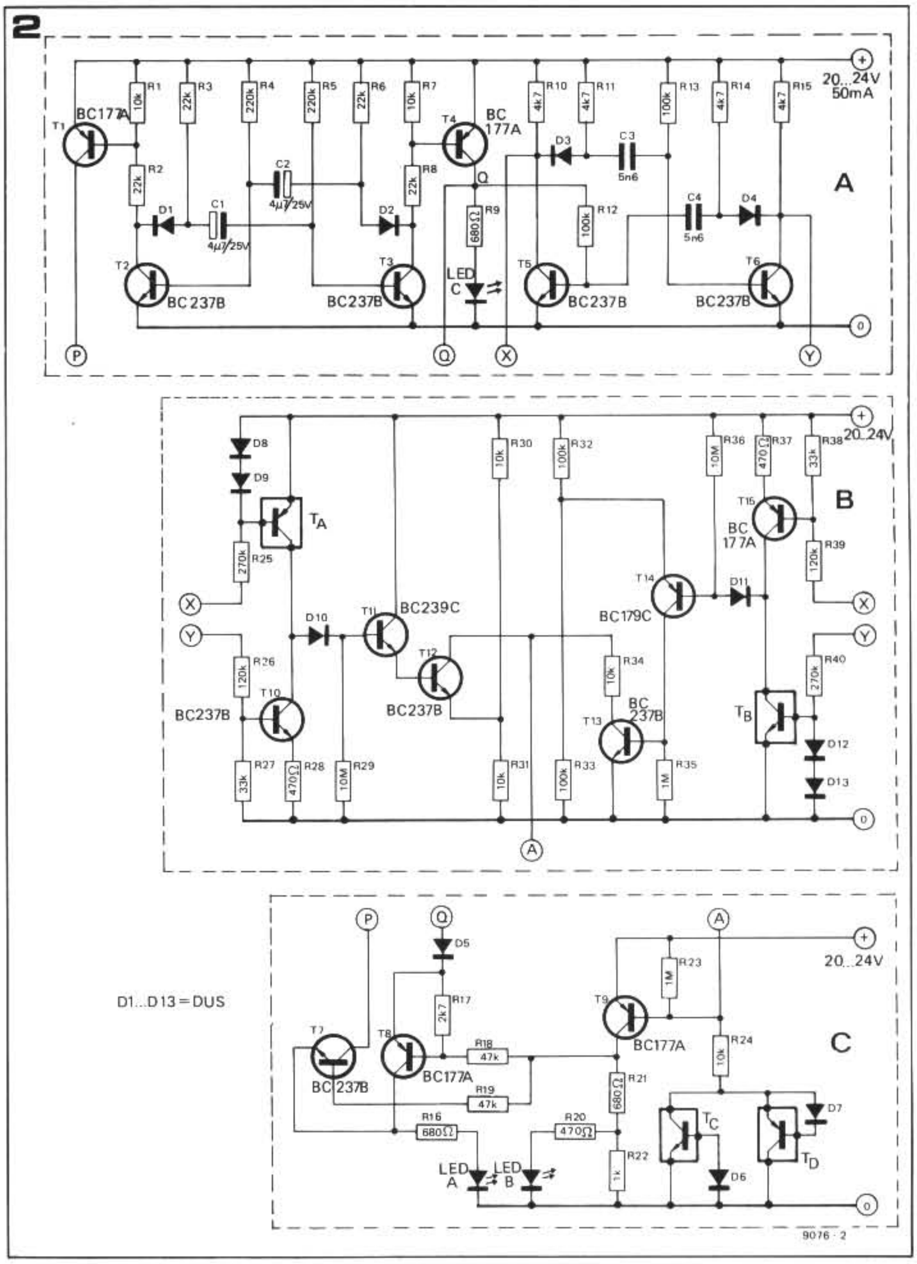


Figure 1. Block diagram of the arrangement for testing a PNP transistor. For clarity, the breakdown voltage test and the complementary test for an NPN transistor have been omitted.

Figure 2. Complete circuit of the TUP/TUN tester. Block A is the collector section, B contains the test bridges for NPN and PNP transistors and C shows the breakdown voltage testing and display sections.

The full display cycle for a 'good' transistor is that both LEDs blink on and off together (figure 3c). It will be seen later that this display occurs only with a transistor which is good according to all the criteria that are tested in socket T_A.

Transistor with low current gain (α')

When the fast oscillator is turned off,

'X' swings positive and 'Y' swings negative, so both T10 and the transistor under test in T_A are cut off. Their commoned collectors are floating, and by the same sequence of events as described for a good transistor, the voltage at the collector of T9 is low and LED 'B' is off. It can be deduced from the table that this combination of switching voltages leads to LED 'A' also being off.

When the fast oscillator comes on and swings 'X' and 'Y' negative and positive respectively, T10 and T_A are both turned on. The potential at the base of T10 is therefore determined by the potentiometer R15 (figure 1a), R26 and R27, i.e.

$$20 \times \frac{33}{4.7 + 120 + 33} = 4.2\ \text{V}.$$

The base-emitter voltage drop in T10 will be about 0.7 V, so the voltage at the emitter of T10 cannot rise above 4.2 V – 0.7 V = 3.5 V. T10 is therefore acting as a current source, its collector current being stabilised at the value determined by this latter voltage and the emitter resistor R28, i.e.

$$\frac{3.5 \times 1000}{470}\ \text{mA} \approx 7.4\ \text{mA}$$

As the emitter of T_A is directly connected to the positive supply rail, its base current is determined by the voltage (about 19 V) between 'X' and the positive rail, and by R25, i.e.

$$\frac{18 \times 10^6}{270 \times 10^3}\ \mu\text{A} \approx 70\ \mu\text{A}$$

(the base-emitter resistance can be disregarded in this context).

It has been mentioned that T10 acts as a current source attempting to stabilise the collector current through both transistors at 7.4 mA, which corresponds to a current gain of something over 100 for the transistor under test. If T_A cannot produce this current, T6 bottoms and the voltage at the connected collectors of T_A and T10 becomes too low for T11 and T12 to be turned on (figure 3d). So the potential at 'A' remains positive and LED 'B' stays off. The table will show that LED 'A' comes on.

When the fast oscillator swings to its other polarity (i.e. 'X' swings positive and 'Y' swings negative) the linked collectors of T_A and T10 revert to the floating condition, so that the Darlington pair T11 and T12 remains non-conductive and 'A' positive. LED 'B' therefore stays off and LED 'A' stays on.

Summarising: the LED display with a transistor of low current gain is that LED 'A' blinks and LED 'B' stays on.

Transistor with high capacitances

When the fast oscillator is turned off, the situation is the same as in both the cases already examined: T10 and the transistor under test are both cut off, and this leads to LED 'A' and LED 'B' both being off. When the fast oscillator comes on and swings 'X' negatively and 'Y' positively, both transistors are turned on, but if T_A has high collector-to-base (C_{cb}) and/or collector-to-emitter (C_{ce}) capacitance, its response is delayed. The voltage rise at its collector is slowed down as these capacitances discharge, but the voltage will probably level off at its 'final' value before the end of the period in which T_A is turned on, and when this happens LED 'B' comes on while LED 'A' stays off (figure 3e).

When, however, T_A and T10 are once more turned off by the swings at 'X' and 'Y', the capacitances can recharge only through the Darlington pair T11 and T12 (which has, by definition, a high input impedance) and through the 10 MΩ resistor R29. The drop in potential at the collector of T_A, as the capacitances recharge, is slower than it would be with a normal transistor, and if the capacitances are too large the potential will not fall far enough to turn T11 off (and therefore LED 'A' on and LED 'B' off) before the time when T_A and T10 are turned on once again. So LED 'B' will stay on, and LED 'A' off, throughout each period when the fast oscillator is turned on.

With slightly smaller capacitances, LED 'A' may come on dimly if the slow recharge of excess capacitance only allows this LED to turn on for a small

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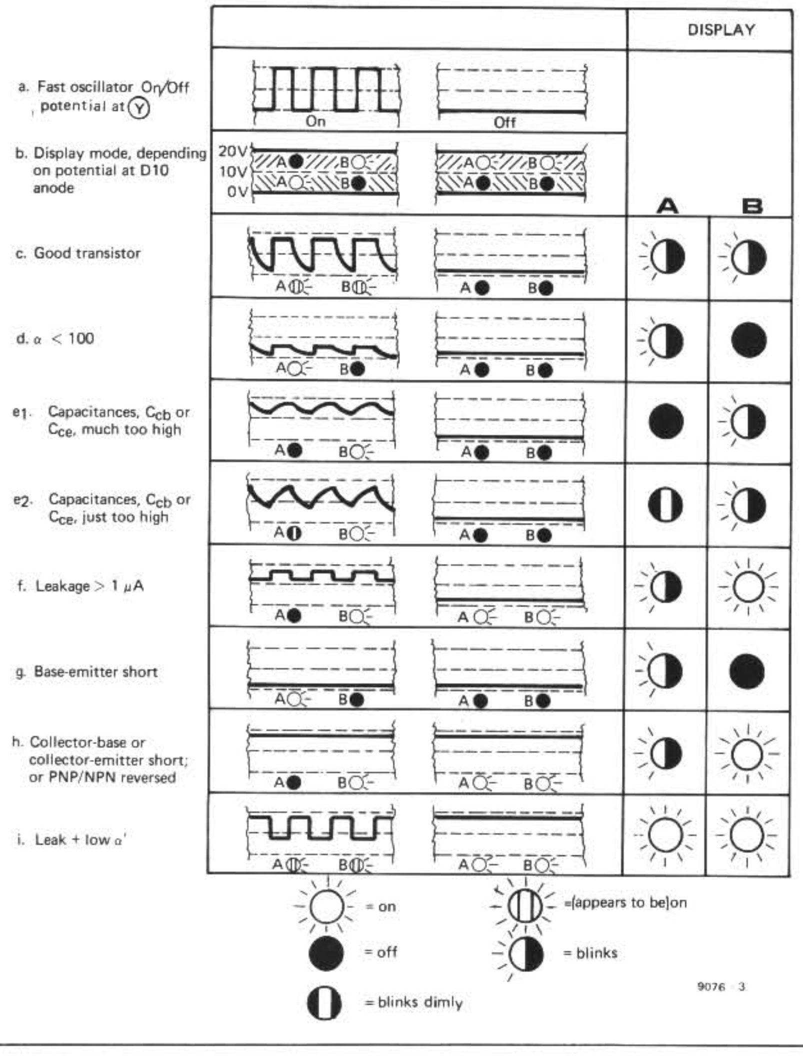

DISPLAY
a. Fast oscillator On/Off potential at Ⓨ
On
Off
b. Display mode, depending on potential at D10 anode
20V
10V
0V
A
B
c. Good transistor
d. α < 100
e1. Capacitances, Ccb or Cce, much too high
e2. Capacitances, Ccb or Cce, just too high
f. Leakage > 1 µA
g. Base-emitter short
h. Collector-base or collector-emitter short; or PNP/NPN reversed
i. Leak + low α'
= on
= off
= blinks dimly
=(appears to be)on
= blinks
9076 3

Figure 3. Summary of LED displays, based on the waveforms at the collector of the transistor under test.

Figure 4. Transistor testing chart, showing what the various displays signify. This chart is derived from figure 3.

Figure 5. Transistor (or diode) breakdown test chart.

Figure 6. The conduction test for diodes, in the 'PNP' test socket, is shown in figure 6A. The leakage test for diodes is shown in figure 6B.

Figure 7. Tests to test the tester.

4

DISPLAY		MEANING
LED A	LED B	
◐	◐	Good transistor
◐	☼	a. PNP/NPN reversed b. Leak > 1 μA c. C-B short d. C-E short
◐	●	a. $\alpha' < 100$ b. B-E short
●	◐	C-B or C-E capacitance > 20p
☼	◐	Leak > 10 μA + very low α' + large C_{cb} or C_{ce}
◍	◐	C_{cb} or $C_{ce} \approx$ 20p
☼	☼	Leak > 10 μA + $\alpha' < 50$
●	●	Impossible. If this happens something is wrong with the tester. Check the power supply!

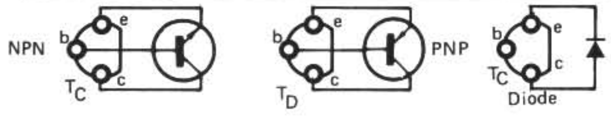
☼ = On continuously ◐ = Blinks

◍ = Blinks dimly ● = Off

9076-4

5

DISPLAY		MEANING
LED A	LED B	
◐	●	Good (Breakdown voltage > 20 V)
◐	☼	Fail (or connections reversed)



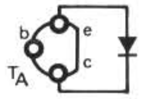
Key to display as for figure 4.

9076-5

6 a

DISPLAY		MEANING
LED A	LED B	
◐	☼	Conducts satisfactorily
◐	●	Not conducting, i.e. open circuit or connections reversed

Key to display as for figure 4.

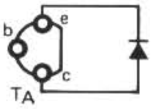


9076-6A

b

DISPLAY		MEANING
LED A	LED B	
◐	●	Blocks satisfactorily
◐	☼	a. Leaks severely b. Shorted c. Connections reversed
☼	☼	Leaks

Key to display as for figure 4



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7

TEST APPLIED	DISPLAY	
	LED A	LED B
1. Nothing plugged into any test socket	◐	●
2. Base and collector or emitter and collector sockets shorted in T_A or T_B.	◐	☼
3. PNP or NPN transistor known to be good, correctly plugged into T_A or T_B as applicable	◐	◐
4. As previous test, but with a 22 p capacitor connected from collector to base or emitter	●	◐
5. Emitter and base leads of a PNP or NPN transistor known to be good connected to the collector and emitter sockets of T_C or T_D, whichever is appropriate; i.e. reverse-diode check of breakdown voltage testing section	◐	☼

Key to display as for figure 4

9076-7

part of each fast-oscillator cycle.

Summarising again: the display for high capacitance is that LED 'B' blinks on and off while LED 'A' remains off or blinks dimly.

Transistor with high leakage

A transistor with high leakage current tends to behave, from the tester's point of view, as though it were turned on all the time. In all the cases examined so far, no collector current flows in the transistor under test while the fast oscillator is turned off. If, however, there is a leakage current between collector and emitter, this will flow through D10 and R29 to the negative rail even when 'X' is positive and both T_A and T10 are supposed to be cut off. This leakage current develops a voltage across the 10 MΩ resistor R29, and therefore raises the potential at the base of T11.

It will be recalled that the emitter of T12 is held at half the supply voltage (i.e. at about 10 volts) by the potentiometer R30 and R31. So if the leakage current is a little more than 1 μA, it will build up a voltage sufficient to turn on T11 and T12 and thus light up LED 'A' and LED 'B' while the fast oscillator is off. When the fast oscillator is turned on and the display transistors are switched through 'P' and 'Q', LED 'B' stays on but LED 'A' goes out (figure 3f). So with a transistor having a leakage current of 1 μA or more, LED 'B' stays on and LED 'A' flashes.

Transistor with base and collector or emitter and collector short-circuited

A transistor with one of these faults 'looks like' one with high leakage (only more so). A current can flow from the positive rail through the emitter-base

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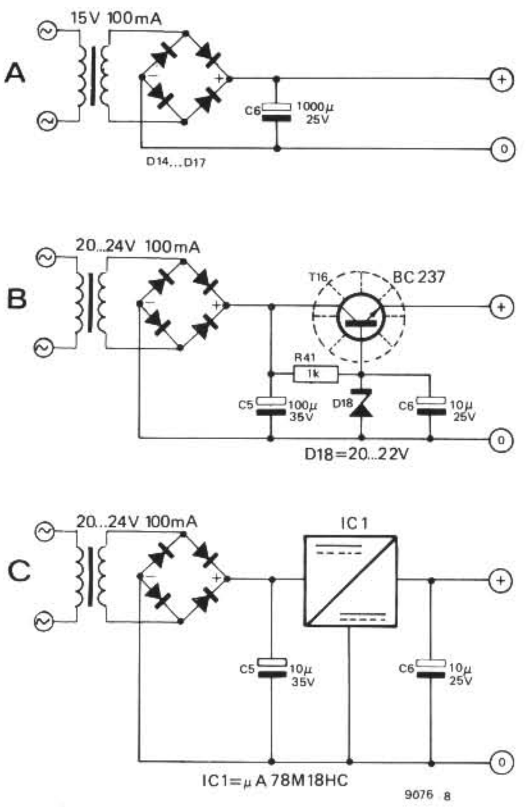

junction and the base-collector short in T_A (or directly through the emitter-collector short), through D10, and through the 10 MΩ-resistor R29. It has been shown that a leakage current as low as 1 µA can turn on T11 and T12 and therefore make LED 'B' light up and LED 'A' go out while the fast oscillator is on. When the fast oscillator is off, LED 'A' lights up and 'B' stays on. So the display with base and collector or emitter and collector short-circuited is that LED 'B' stays on all the time, and LED 'A' blinks on and off (figure 3h).

Transistor with base and emitter short-circuited

When the base and emitter are short-circuited, no 'normal' base current can flow, and therefore there is no collector current. So the transistor 'looks like' one with zero α', and the LED display is the same: i.e. LED 'A' blinks and LED 'B' stays off (figure 3g).

Combined leak and low current gain or combined leak and base-emitter short

While the fast oscillator is off, the display is the same as for a leaky transistor: both LED 'A' and LED 'B' are on. When the fast oscillator is on and is turning T_A and T10 off, the leakage current holds the collectors of T_A and T10 high enough in potential to turn on T11, resulting in LED 'A' being off and LED 'B' being on. When the fast oscillator turns T_A and T10 on, the low current gain of T_A allows T10 to 'overcome' both the leakage current and the collector current (if any) in T_A and pull down the potential of the commoned collectors, whereupon LED 'A' comes on and LED 'B' goes off. This alternate lighting up of LED 'A' and LED 'B' is at the speed of the fast oscillator, and both LEDs stay on while the fast oscillator is turned off, so we have a display cycle in which both LEDs appear to be on continuously (figure 3i).

Figure 8. Alternative power supply arrangements, depending on the components one can obtain.

Figure 9. The p.c.b. and component layout for the TUP/TUN tester. Three alternative layouts are given, corresponding to the three power supply arrangements.

Other combinations of Faults

It would not be a very profitable exercise to list the LED displays with all possible combinations of faults, but it can be said that only a transistor which is 'sound in wind and limb' according to all the test criteria will give the 'good transistor' display in both test sockets.

PNP and NPN transistors

The foregoing descriptions apply to PNP transistors. They also hold good, mutatis mutandis, for NPN transistors plugged into test socket T_B, which appears on the right-hand side of figure 2b. The functions performed by T10, T11 and T12 and associated components for PNP transistors are performed by T13, T14 and T15 and associated components for NPN transistors. In this case, however, the transistors T13 and T14 which pass on a voltage drop at the anode of D11 are not a Darlington pair but a complementary PNP-NPN-pair.

If a transistor is plugged into the wrong test socket (PNP into an NPN socket or vice versa), the base-to-collector path becomes equivalent to a forward-connected diode, and the display is the same as for a transistor with a base-collector short. The transistor will not be damaged, and it is clearly a good thing, when one shows up unexpectedly as 'faulty', to check whether it has been plugged into the wrong holes!

Breakdown Voltage Test

The sockets for this test are T_C and T_D, shown in figure 2c. The effective breakdown test voltage is about 20 V, and if a breakdown current flows the voltage at 'A' is pulled down continuously, resulting in LED 'A' blinking and LED 'B' staying on throughout the cycle. For a transistor which passes this test, LED 'A' blinks and LED 'B' stays off all the time (figure 5).

Diode Tests

By plugging the anode and cathode leads of a diode into the emitter and collector sockets of the PNP test points (or the other way round with the NPN test points) it can be tested for forward conduction, leakage and breakdown voltage. When the fast oscillator is off, the junction of the diode cathode and the collector of T10 will be held positive by the conduction of the diode, and if the conduction is good enough, this junction will remain positive when T10 is turned on (through 'Y') by the fast oscillator. When T10 is turned off the junction will still be positive. This leads to a display cycle in which LED 'A' blinks and LED 'B' stays on continuously (figure 6).

When the diode is non-conducting, open-circuited or connected the wrong way round, the junction of T10 collector and the cathode (or anode) will remain negative throughout the oscillator cycle, giving a LED display in which 'A' blinks and 'B' remains off. When a diode is deliberately connected the wrong way round, this display gives an indication (if the diode is a good one) that it is blocking properly in the reverse direction. If a diode is short-circuited or is leaking severely, it will give the same display, when plugged in the wrong way round, as a good diode connected the correct way round. It is just possible, however, that it *is* a good diode plugged

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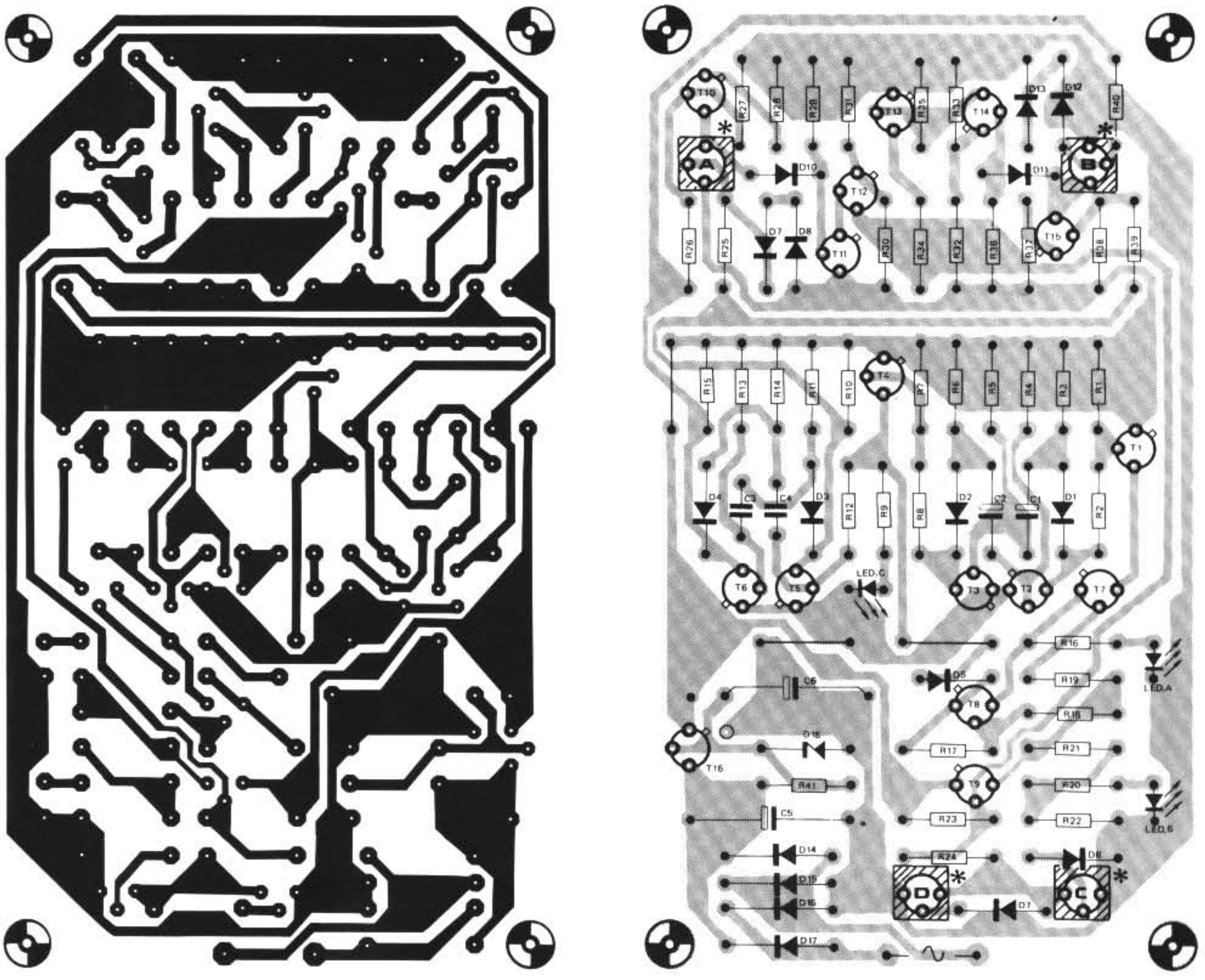


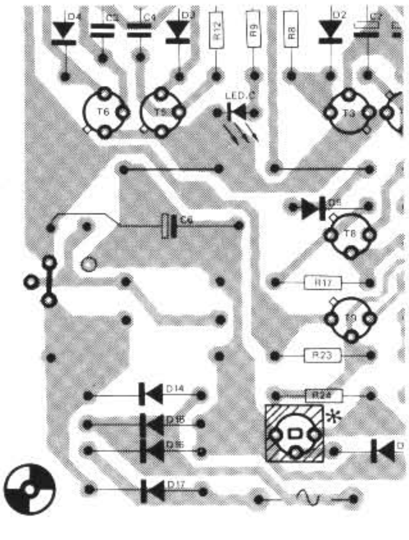
Stabilised supply with discrete components
Tr = 20 V/100 mA
R41 = 1 k
C5 = 100 µ/35 V

C6 = 10 µ/35 V
T16 = BC237B
D18 = 20 V Zener

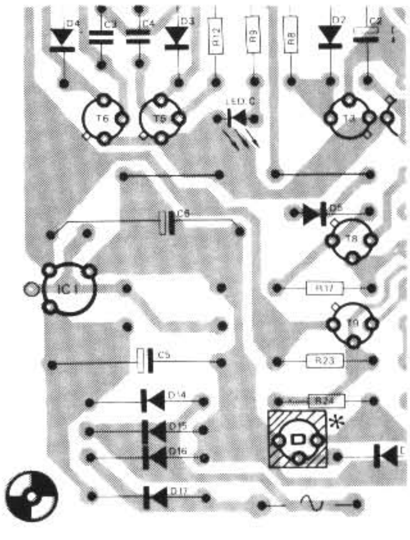
Parts list
Resistors:
R1, R7, R24, R30, R31, R34 = 10 k
R2, R3, R6, R8 = 22 k
R4, R5 = 220 k
R9 (if used), R16, R21 = 680 Ω
R10, R11, R14, R15 = 4k7
R12, R13, R32, R33 = 100 k
R17 = 2k7
R18, R19 = 47 k
R22 = 1 k
R25, R40 = 270 k
R26 = 120 k
R27, R38 = 33 k
R28, R37, R20 = 470 Ω
R29, R36 = 10 M
R23, R35 = 1 M
R39 = 120 k
R40 = 270 k

Capacitors:
C1, C2 = 4µ7
C3, C4 = 5n6

Semiconductors:
T1, T4, T8, T9, T15 = BC307B or equ.
T2, T3, T5, T6, T7, T10, T12, T13, T16 = BC237B or equ.
T11 = BC239C or equ.
T14 = BC179C or equ.
D1 … D17 = BAX13, BY126, BY127, 1N4002, or other general-purpose silicon diodes
2 x LEDs



Unstabilised supply
Tr = 18 V/100 mA
C6 = 1000 µ/25 V



Stabilised supply with IC
Tr = 20 V/100 mA
C5 = 100 µ/35 V
C6 = 10 µ/35 V
IC = µA78M18HC or equ.

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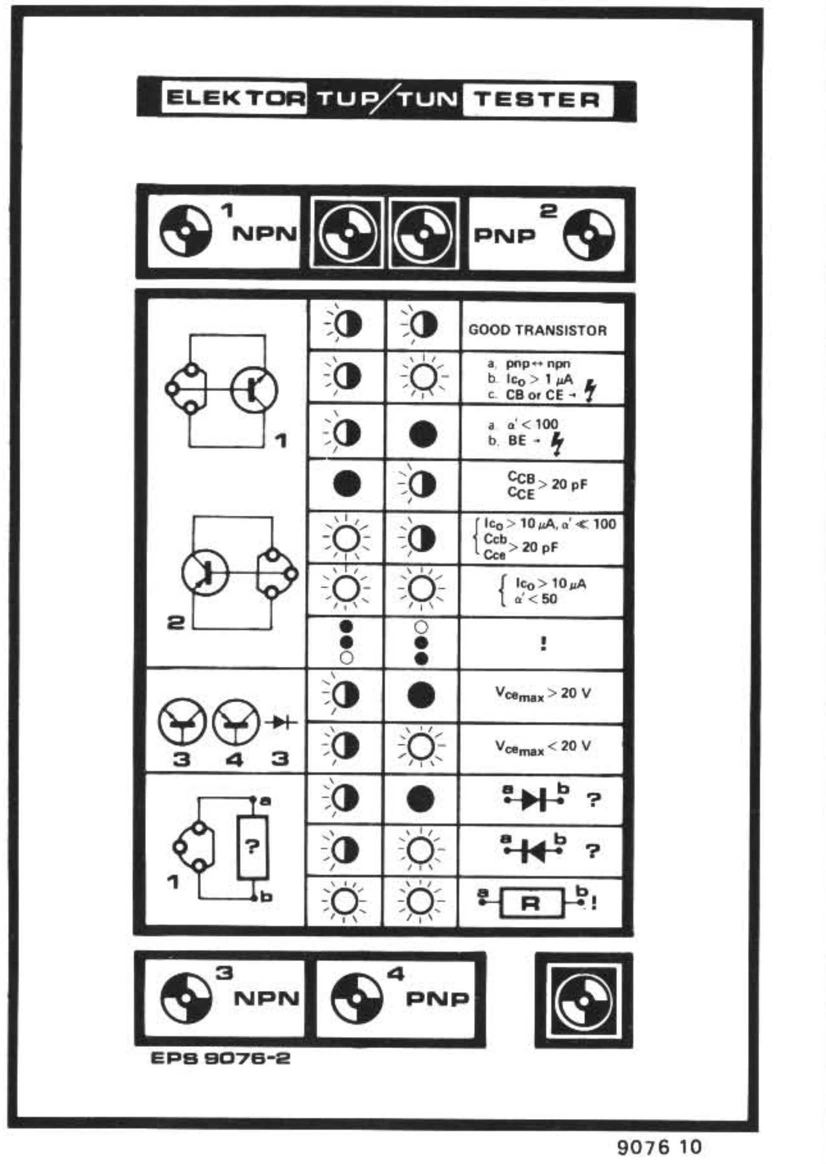


Figure 10. Front panel design for the tester. This panel is available via the Elektor print service, with black lettering on an aluminium-coloured background, as a self-adhesive label.

in the correct way round, i.e. that one has mistakenly connected it this way instead of reversing the connections. So it is important to make tests in both polarities if ambiguities are to be avoided.

If a diode which leaks moderately is plugged in the wrong way round, the leakage current may be enough to hold the anode of D10 positive while T10 is turned off, but not while T10 is turned on. This will give a display in which both LEDs appear to be on continuously – the same as for a transistor which is both leaky and low in current gain.

General

Figure 3 summarises the LED indications when the fast oscillator is on or off, and for different potentials at the anode of D10 in the main PNP testing section. The difference between this figure and table 1 is that the table is based on the fast oscillator and point 'A', which is common to the main testing circuits and to the breakdown voltage testing circuit. The relationship between the potential at the anode of D10 and the potential at 'A' when the main PNP testing section is in use is that a high potential at the anode of D10 produces a low potential at 'A' and vice versa. Figures 4, 5 and 6 summarise the meanings of the possible LED indications for various tests. Figure 4 is, of course, derived from figure 3. The front panel design (figure 10) summarises all three figures.

Construction and testing

Unless one has access to an independent means of testing the transistors and diodes, these should be ones which carry the manufacturers' warranty. Resistors should have 5% tolerance.

Figure 9 shows the p.c. board and the component layout for the complete tester (with the exception of the mains transformer). It should be noted that the emitter and collector connections to the test sockets appear to be interchanged, but when the sockets are mounted on the copper side of the board the connections will be correct. This facilitates the mounting of the board flush under the top panel, without the other components getting in the way.

As it is not possible to give meaningful voltage or current test values for individual transistors, which might help to localise mistakes or faults, the construction should be checked very carefully. Even if one does not intend to use the optional LED 'C', one of the LEDs which will ultimately serve as 'A' or 'B' can be 'borrowed' at the constructional stage to serve temporarily as 'C' and thus give a check whether the slow oscillator (T2 and T3) and also T4 is working. The actual value of the nominally 680 Ω resistor in series with 'C' is not critical. If the temporary 'C' is seen to blink at about the right rate, test number 1 of figure 7 will show whether T8 is also working. Test number 2 will show whether T7, T9, T11 and T12 are working if the short is put into test socket T_A, and T7, T9, T13 and T14 with the short in test socket T_B.

To check the complete PNP and NPN testing sections, including the breakdown voltage test, one will need spare PNP and NPN transistors known to be sound, in addition to those used in building the tester. Only a transistor with normal current gain, or with a particular combination of faults, can produce a display in which LED 'B' blinks.

Once the two good transistors have been seen to give the display for test number 3 of figure 7, the more refined test number 4, which simulates the effect of excessive capacitance, can be applied. A 22 pF capacitor should be enough to make LED 'A' black out altogether, but it may be of interest to experiment with different lower capacitor values to find what value of capacitor is just low enough to allow the waveform at the junction of T_A and T10 to extend below the critical level (about 10 V) and cause LED 'A' to blink dimly, as shown in figure 3e$_2$.

The emitter-base junction of a transistor forms a diode with a reverse breakdown voltage of about 5 V, so one of the transistors used in the foregoing checks can also be used to check the breakdown voltage testing section (figure 7; number 5). One must make sure that it is connected the right (or is it the wrong?) way round.

Power Supplies

Three different possibilities are offered for a mains power supply unit (figure 8): a simple unstabilised unit, a stabilised unit with the stabilisation circuit built up from three discrete components, or a stabilised unit using an IC. The unstabilised unit uses a transformer with an 18 V secondary – which may sometimes be difficult to obtain – and a 1000 µ capacitor. If either of the stabilisation circuits is used, the capacitor can be much smaller. The 20 V transformer used in these circuits should be more readily obtainable.

The transistor or IC should have a heatsink. ◼

J.W. van Beek

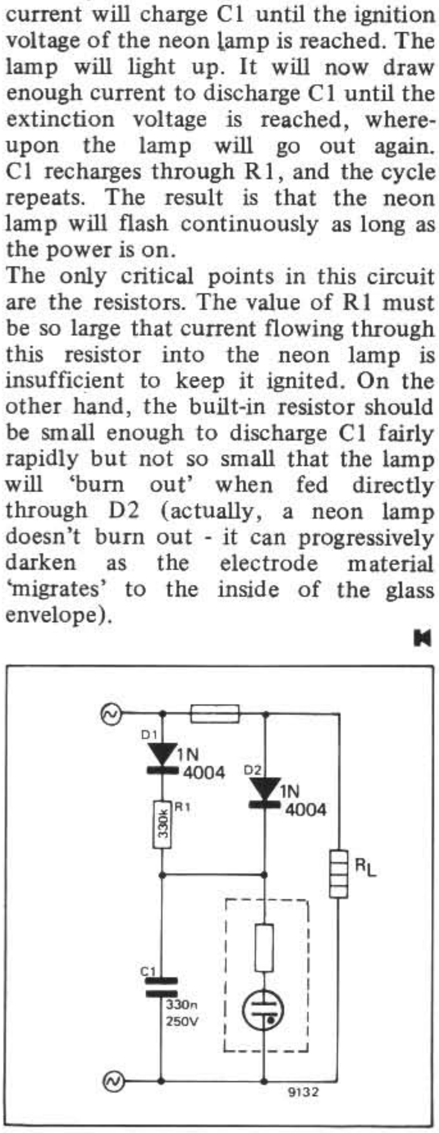
fuse indicator

In this circuit, the neon indicator lamp shows whether or not the power is on and whether or not the fuse is blown.

As long as the power is on and the fuse is intact, the neon lamp will draw current through the fuse, D2 and the built-in series resistor. It will burn brightly to indicate that all is well.

If the fuse is blown, however, current can only flow through D1 and R1. This current will charge C1 until the ignition voltage of the neon lamp is reached. The lamp will light up. It will now draw enough current to discharge C1 until the extinction voltage is reached, whereupon the lamp will go out again. C1 recharges through R1, and the cycle repeats. The result is that the neon lamp will flash continuously as long as the power is on.

The only critical points in this circuit are the resistors. The value of R1 must be so large that current flowing through this resistor into the neon lamp is insufficient to keep it ignited. On the other hand, the built-in resistor should be small enough to discharge C1 fairly rapidly but not so small that the lamp will 'burn out' when fed directly through D2 (actually, a neon lamp doesn't burn out - it can progressively darken as the electrode material 'migrates' to the inside of the glass envelope).



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disc preamp

A preamplifier-equaliser for magnetic pickup cartridges has to meet quite exacting requirements. Values for gain, noise level and maximum input voltage which will guarantee trouble-free operation under all conditions are not so easy to achieve. The well-known two-transistor configuration, operating from a 12 . . . 18 V supply, invariably falls short on gain and overdrive-margin - unless it is designed for a low nominal output voltage (about 30 mV). An alternative approach is to make use of a good integrated amplifier. The design about to be described, which meets all the requirements, employs a SN 76131. An almost identical I.C. is the μA 739.

To make optimum use of the possibilities for groove-modulation, gramophone records are cut with low audio frequencies attenuated and high audio frequencies boosted (with respect to 1 kHz). To simplify playback equalisation, a single weighting curve has been standardised throughout the world - the IEC disc-cutting characteristic. (This curve originated as the RIAA standard: Record Industry Association of America).

The disc-cutting engineer arranges for a '0 dB standard (reference)level' in the taped programme to produce a stylus tip-velocity about 14 dB below the 'safe' drive-level, to provide headroom for instantaneous signal peaks. 0 dB standard level (corresponding roughly to the average level in loud passages) is typically 39 mm/sec tip peak velocity at 1 kHz. Standard level on carrier-channel discs (CD4 and UD4) is lower, about 22 mm/s.

Experience indicates that wide-band cartridges suitable for carrier discs deliver 70 . . . 140 μV for each mm/sec of tip velocity. The usual 'hifi' cartridges deliver about 6 dB more. (Note that sensitivity specifications are usually given in RMS millivolts per peak centimetre per second). So the input to the preamplifier at standard level 1 KHz will be about 1 . . . 10 mV peak.

What are the consequences of all this for the preamplifier?

Suppose it is the intention that the output voltage at standard level be about 100 mV RMS with the lowest-output cartridge. The closed-loop gain must therefore be 100 at 1 KHz. Now allow 20 dB of extra gain for IEC equalisation at the lowest frequencies, not including 20 dB of negative feedback (which should reasonably be maintained at the 'low end'). This tots up to an open-loop gain of at least 80 dB! Ten thousand times. That seems to eliminate the two-transistor configuration.

The SN 76131 integrated circuit, with the chosen lag compensation, has a typical open-loop response according to the upper dashed curve in figure 1. The

Figure 1. The desired closed-loop gain curve follows the IEC (RIAA) disc equalisation characteristic, with a mid-band gain (1 KHz) of 40 dB (heavy line). The open-loop gain must be at least 20 dB greater; the SN 76131, with the chosen lag compensation, provides this with a margin of about 10 dB (upper dashed curve).

Figure 2. The heavy line is an estimated contour for the highest voltage delivered to the preamplifier by a high-output dynamic cartridge. The preamplifier cannot be overdriven by the highest input voltage; the upper dashed line is the overdrive threshold for the disc-preamplifier with SN 76131. This clears the maximum-input contour by approximately 10 dB.

Figure 3. The maximum RMS output level produced by the preamp when used with a high-output cartridge follows the thick contour. The dashed line indicates the maximum output capability. The safety margin is here once again about 10 dB.

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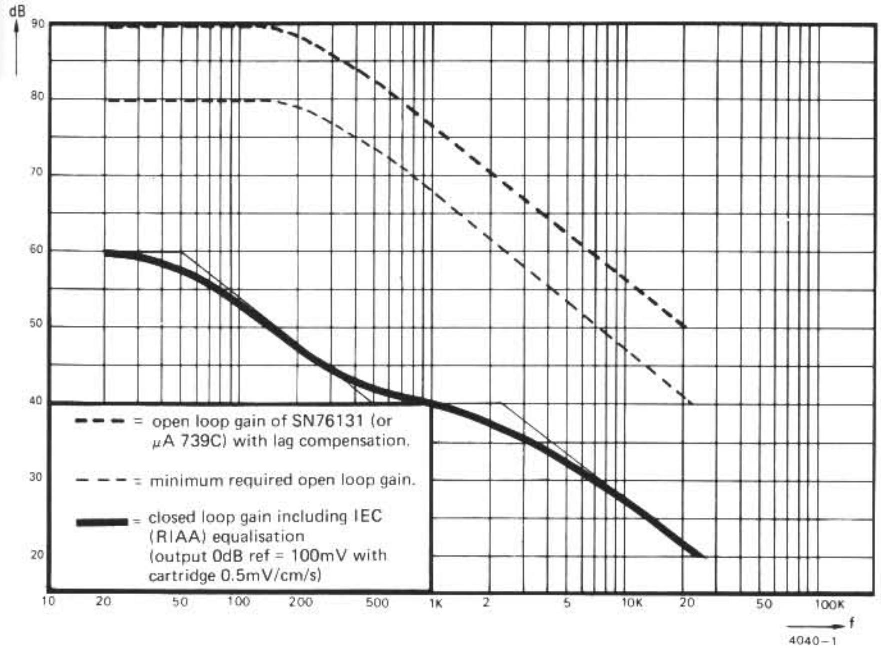

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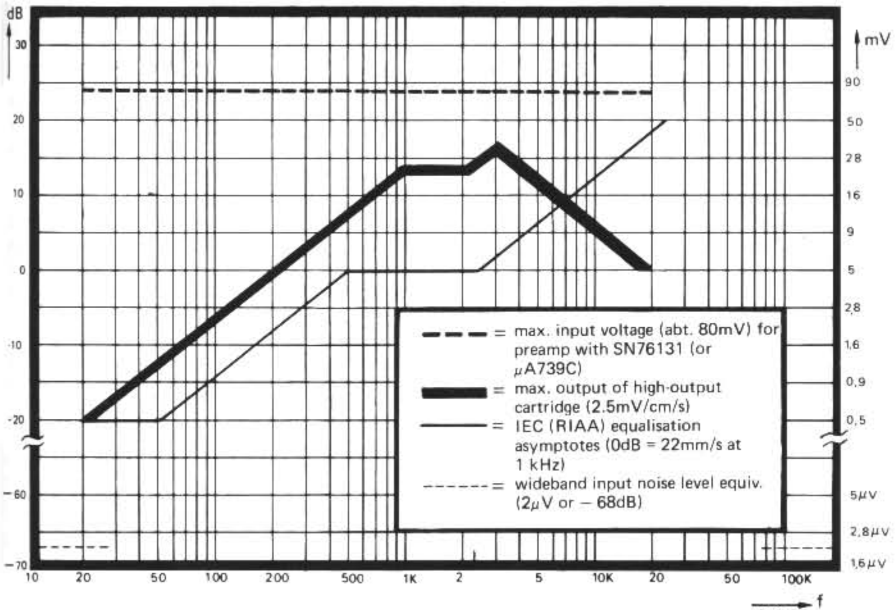

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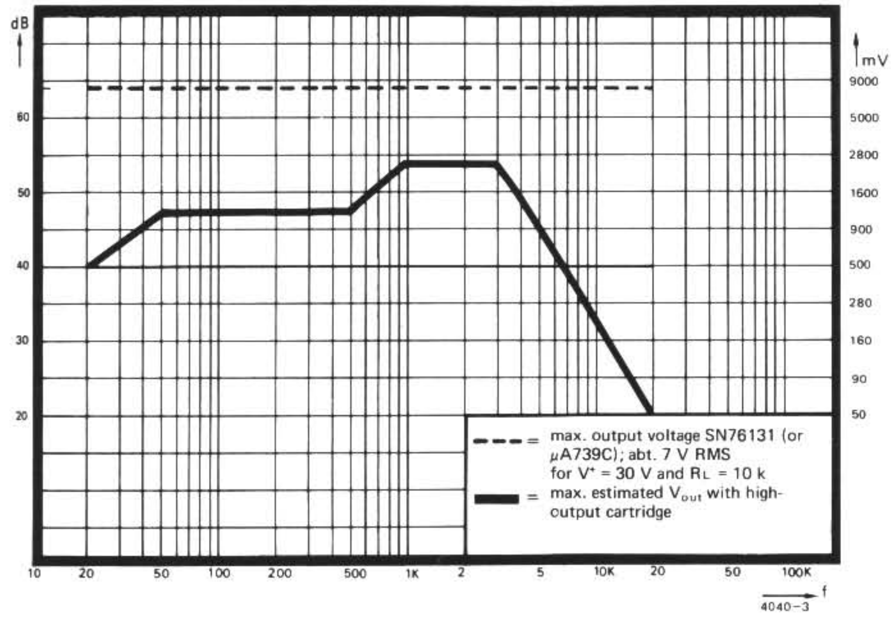

lower dashed curve indicates the minimum requirement (80 dB at the low end, reducing as the closed-loop gain – i.e. the bold line in figure 1 – falls according to the IEC curve). The conclusion is that there is about 10 dB of open-loop gain to spare at all frequencies, which will accomodate IC-tolerances etc.

Overdriving the input

To find the maximum input voltage which can occur, one must start with the highest-output cartridge. This will deliver, as shown earlier, about 5 . . . 10 mV peak at standard level.

The maximum level encountered on the disc is nominally +14 dB relative to standard level. This indicates a nominal maximum input voltage of 25 . . . 50 mV. (At 1 KHz of course). It is clearly advisable to regard this figure, with due respect, as nominal. One might encounter a cartridge with still higher output or some disc manufacturer may fully exploit tracing-compensation, to cut a clean signal at more than +14 dB . . . The absolute limit (set by 'slope-overload' at the inner radius of LP discs) is presently about 350 mm/s (+18 dB) – but a 33 disc also has outer grooves and they can be cut at a level 6 dB higher. This means that in theory the maximum output level for the highest output cartridge is about 200 mV! With the circuit arrangement given, the SN 76131 will accept 80 mV at the input (thick dashed line in figure 2).

The same figure can be used to estimate the effect of amplifier noise. The wideband noise level, referred to the SN 76131 input, is 2 μV (RMS). This is –68 dB in the figure (0 dB = 5 mV RMS). For the least sensitive cartridge, this noise level is –54 dB relative to standard level for CD-4 or UD-4 discs. Assuming maximum signal level to be +14 dB the overall S/N ratio is (for this worst case) 68 dB. Manufacturers estimate that the S/N ratio possible with a first-rate LP pressing is about 70 dB. Conclusion: pass.

Figure 2 can be used once more to determine the hum-level requirements. The IEC bass-lift now aggravates matters: to achieve a hum level 60 dB below standard level, with a fairly high-output cartridge (5 mV RMS at 1 KHz), it becomes necessary to keep the hum voltage at the input below 1 μV! This can be achieved, in general, by providing good screening for the input circuit and for the preamplifier itself (signal-return inside the cable-screen, the latter bonded to signal-earth at the amplifier end only), and by properly smoothing (preferably regulating) the DC supply.

The sensitivity of the SN 76131 to interference on the DC supply rail is quoted – under operating conditions rather different to the above – as 50 μV/V. (i.e. 50 μV apparent input for each volt of supply disturbance). To achieve the 1 μV hum level just mentioned means keeping supply ripple below 20 mV. A simple active circuit will readily meet this requirement;

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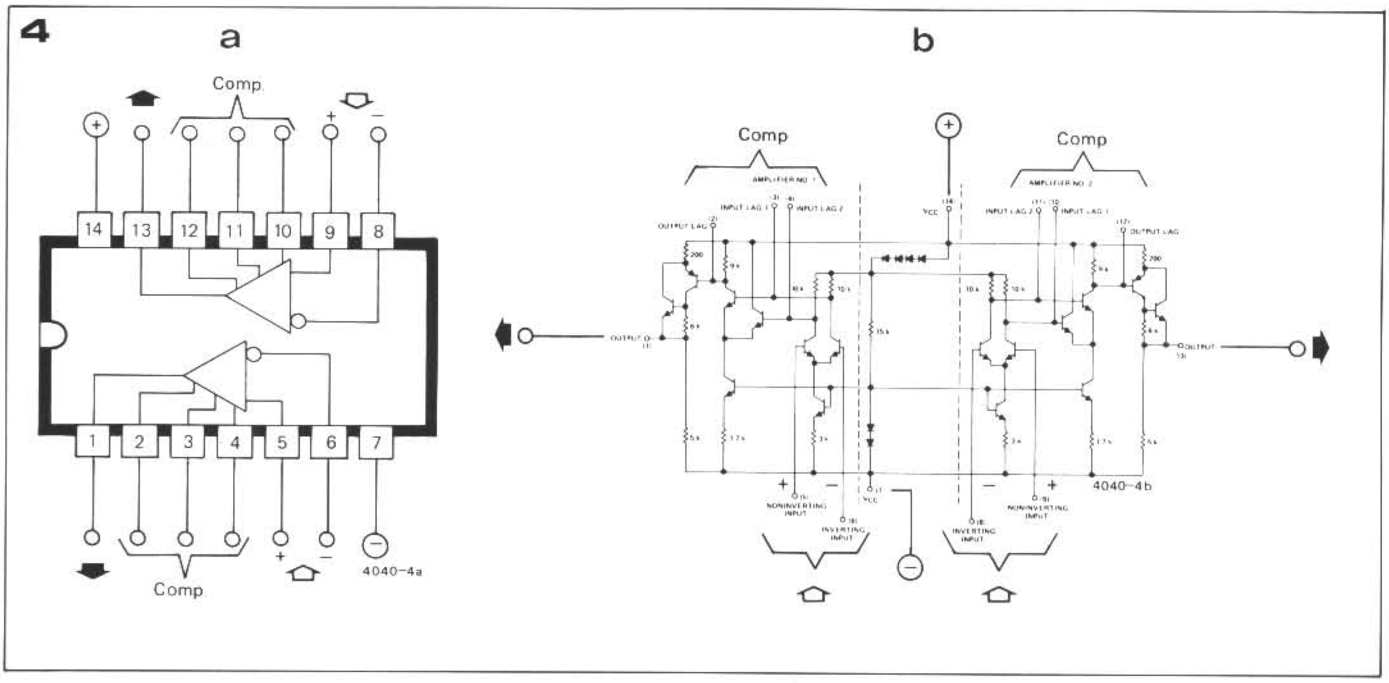

simple smoothing of a 'raw' DC supply would probably be inadequate or too expensive (or both!).

Clipping at the output

The requirement that the input circuit is not overdriven will not by itself quarantee that the amplifier as a whole operates within limits. The output circuit can still 'run out of' voltage or current swing.

Taking the combination of a sensitive cartridge and the maximum disc modulation likely to be encountered, one can estimate the highest level of output signal that the preamplifier will have to deliver. This can be done by combining the closed-loop gain characteristic (figure 1, thick line) with the maximum cartridge output contour (thick line in figure 2). The result is shown in figure 3 (thick line). The conclusion is that the voltage swing at the output can be as high as 2.5 V RMS (7 V p-p).

The clipping level for the SN 76131 depends on the supply voltage and on the load impedance. The case of $V^+ = 30$ and $R_L = 10$ K, where the IC can deliver about 7 V RMS, is shown dashed in figure 3. This reserve should take care of all eventualities. If one considers a brink-of-disaster capability of 3 V RMS, then the combinations 18 V/5 K, 14 V/10 K and even $V^+ = 12$ (at $R_L = 50$ K) are in order. Even under these conditions, current clipping due to the load of the feedback network on the output (at the highest audio frequencies) and slew-rate limiting (due to the early open-loop rolloff) are not expected to occur.

Integrated circuit

The circuit was designed around the specified SN 76131 by Texas Instru-

Figure 4. The pinning of the IC's SN 76131, TBA 231, TCA 590C, µA 739C and LM 1303 (figure 4a) is identical. The internal circuit diagram (figure 4b) however only applies to the SN 76131.

Figure 5. The circuit diagram of the equaliser-preamplifier. An integrated voltage regulator, when required, can be connected between the points A and B (see text).

Figure 6. PC board and component layouts for the equaliser-preamplifier. All external connections are made to one edge of the PC board, so that it can be used as plug-in module in a complete control amplifier.

Figure 7. Illustration of the preamplifier board as plug-in module.

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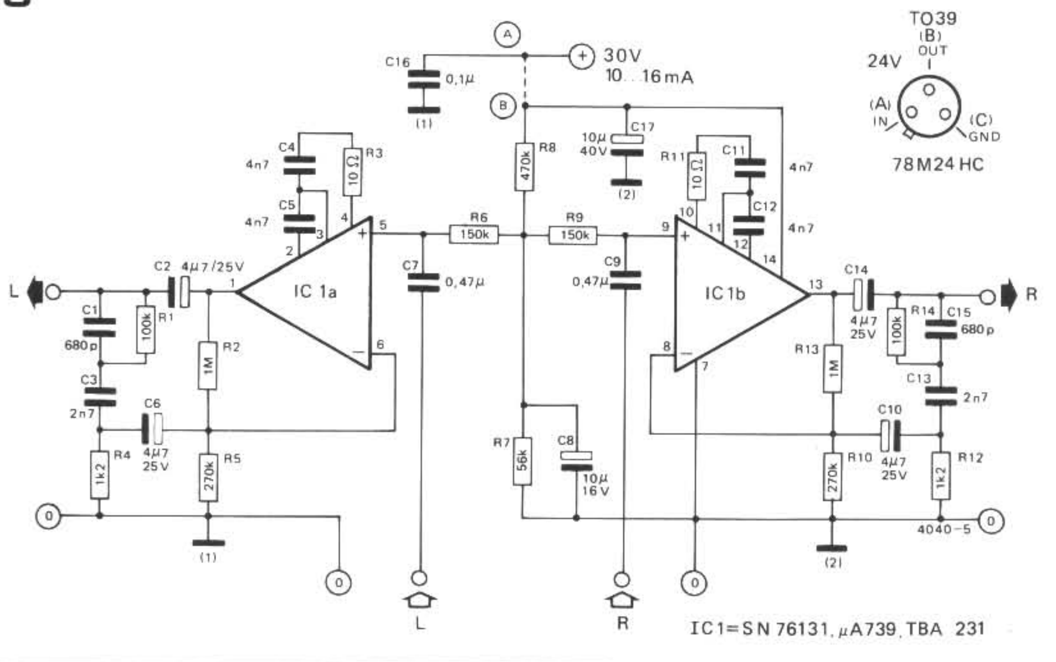

Parts list to figure 5.

Resistors:
R_1,R_{14} = 100 k
R_2,R_{13} = 1 M
R_3,R_{11} = 10 Ω
R_4,R_{12} = 1k2
R_5,R_{10} = 270 k
R_6,R_9 = 150 k
R_7 = 56 k
R_8 = 470 k

Capacitors:
C_1,C_{15} = 680 p
C_2,C_6,C_{10},C_{14} = 4µ7, 25 V
C_3,C_{13} = 2n7
C_4,C_5,C_{11},C_{12} = 4n7
C_7,C_9 = 0.47 µ
C_{16} = 0.1 µ

Semiconductors:
IC_1 = SN 76131, µA 739C, TBA 231

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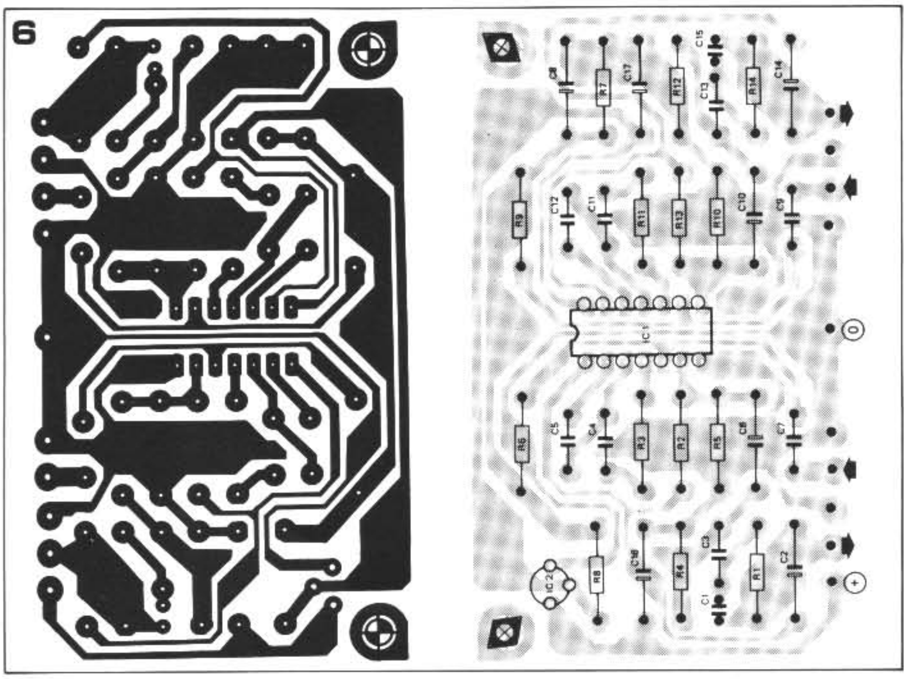

Table 1. The most important specifications of the SN 76131 and μA 739C.

V^+ max.	36 V
V_{in} max.	±5 V
P_{tot} max.	500 mW
V_{out} swing	1 . . . 26 V*
Open loop gain typ	18000*
Open loop gain min	6500*
Z_{in} typ.	150 KΩ*
Z_{in} min.	37 KΩ*
Z_{out} (1 KHz)	5 KΩ*
Crosstalk (10 KHz)	–140 dB*

* These values apply for $V^+ = 30$ V; $R_L = 50$ KΩ

Table 2. Main specifications of the disc preamplifier described here.

Voltage gain, 1 KHz	40 dB
Equalisation IEC	±1 dB
Max. input (RMS)	80 mV
Max. output (RMS)	7 V
Input noise level	2 μV
S/N ratio	55 . . . 70 dB*
Crosstalk (1 KHz)	–80 dB
T.H.D.	⩽0.1%

* see text

ments. According to the maker's data sheets, the Fairchild μA 739C and the SGS TBA 231 are almost identical and should perform well in the circuit. The three IC's are pin compatible (see figure 4a). Two other IC's with the same pinning are the Philips TCA 590 C and the LM 1303 by National Semiconductors. This last device has lower specifications for gain, noise and drive level – it will probably work acceptably in the preamplifier, but we have not checked this.

The internal circuit of the SN 76131 (and the TBA 231) is given in figure 4b. Except for the output transistor, the μA 739C is identical. Table 1 lists the most important characteristics of the device. The TCA 590C has an additional class B output stage, while the LM 1303 circuit dispenses with the stabilising diodes and with the current sinks for the second long-tail pairs.

The external circuit

Figure 5 gives the complete circuit diagram of the equaliser-preamplifier. The open-loop response is set up by $C_4/C_5/R_3$ and $C_{11}/C_{12}/R_{11}$; it follows the appropriate dashed curve in figure 1. The IEC correction networks are $R_1/R_2/R_4/C_1/C_3$ and $R_{12}/R_{13}/R_{14}/C_{13}/C_{15}$. R_5 and R_{10} take care of the DC biassing. With the values given, the correction obtained using 5% components is within 1 dB of the IEC (RIAA) standard.

The input blocking capacitors C_7 and C_9 should not be replaced by larger values or by electrolytics. This could lead to undesirable switch-on phenomena ('plop' or even momentary oscillation). The values given will not affect the bass response (which is 1 dB down at 20 Hz).

It has already been pointed out that the supply ripple must be well filtered. A typical regulated supply will meet the requirements, but a 'raw' supply followed by resistor-electrolytic filter will usually cause too much hum. In this case one can use an IC voltage regulator which will deliver 24 . . . 30 V at 15 mA (or more), e.g. the Fairchild μA 78M24HC. The printed circuit board (figure 6) has a position for this regulator. If such a device is not to be used, the points A and B should be bridged.

To simplify assembly, all external connections have been placed at one edge of the PC board, using standard grid-spacing. This means that it is possible to mount the disc preamplifier as a plug-in module on a suitably designed control amplifier board (figure 7).

Table 2, in conclusion, summarises the most important specifications of the equaliser-preamplifier for disc records.

Lit.: Texas Instruments data sheets for SN 76131.

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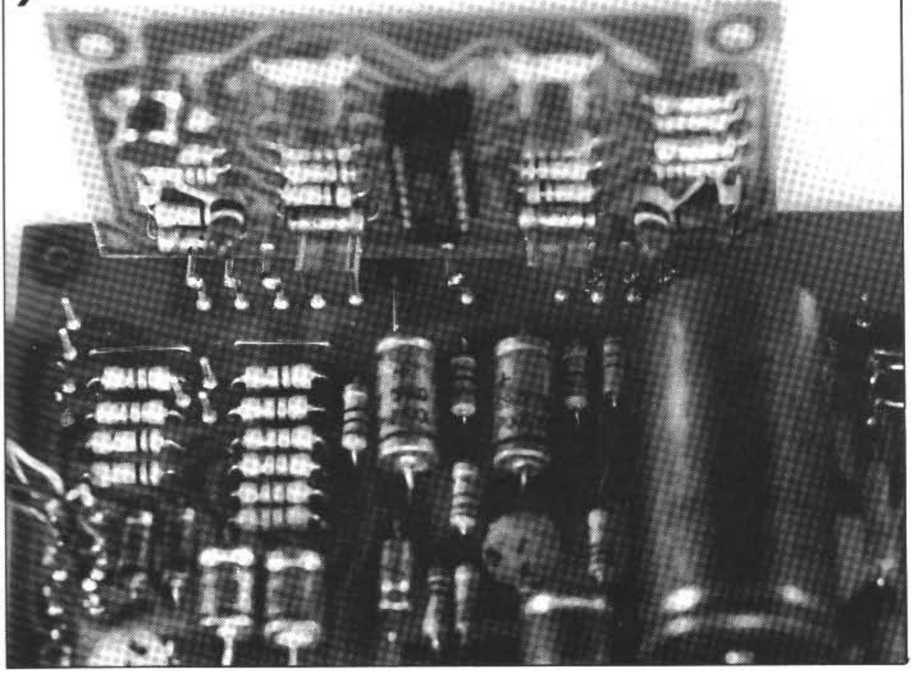
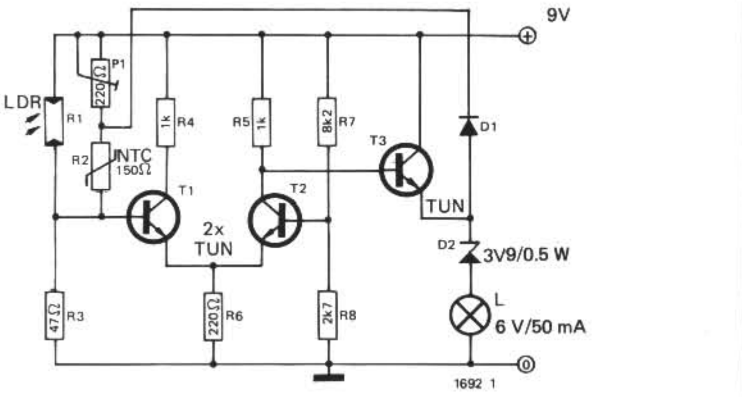


electronic candle

The starting point for design of this electronic candle was a desire to reduce the fire risk associated with the Christmas season, at the same time providing a candle which would not burn up so quickly. Naturally, the electronic candle can be lit with a match (but a pocket torch will do the job too!); it can be blown out or 'nipped out' with the fingers.

1



The circuit is very simple. In the condition 'candle out' no current flows in T1 and T2 is saturated. A certain pre-heat current is passed through the NTC-resistor (R2) via P1. This trimmer has to be adjusted so that the candle is just not 'self-igniting'. Strong illumination of the LDR (R1) will cause T1 to conduct. The circuit is arranged so that even bright room lighting will not cause things to happen — a burning match held close to the LDR will however do the trick nicely.

2

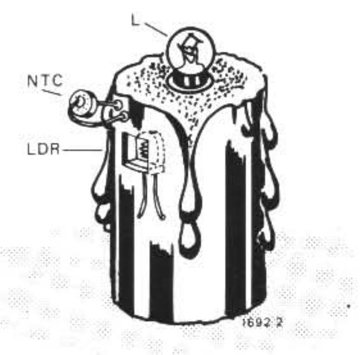


Figure 1. Circuit diagram for the 'electronic candle'. P1 is adjusted so that the lamp just does not light up spontaneously. The candle is 'lit' by holding a match (or a torch) close to the LDR, and 'put out' by blowing on the NTC.

Figure 2. A sketch of one possible construction method. The candle is made from a piece of PVC electric-wiring conduit.

When T1 starts to conduct, the current through T2 is reduced until ultimately this transistor cuts off. T3 will meantime start to conduct, lighting the candle flame. As T3 approaches saturation an extra heating current flows via D1 into the NTC, causing this to drop in resistance value. If the match is held long enough in position — it should almost burn down to the fingers — the circuit will hold in the 'candle lit' condition.

The candle can be blown out if one blows long and hard enough on the NTC. The ultra-slow triggering action of starting up is now reversed and the lamp-current falls away to zero — the flame goes out. It is also possible to 'nip out' the candle by cooling the NTC between two fingers. The prototype candle used a miniature NTC having a resistance at room temperature of about 150 ohm.

If desired, one can replace the zener-diode D2 by 5 series-connected DUS universal diodes. ◼

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recip-riaa

The performance of bought or self-built preamplifiers for magnetic pickup cartridges is invariably not sufficiently well known. This is mainly due to the

Carrying out measurement on a disc-preamplifier involves two specific, normally time-consuming complications. First of all, one cannot straightforwardly check the frequency response; carrying out such a check on the dynamic preamplifier requires a point-by-point comparison of the meter reading with a voltage-frequency table.

This brings us to the second complication. A correct test of the nominal or maximum available output voltage as a function of frequency is only obtained when the input voltage follows the weighting curve used during cutting (figure 1). The simple and direct solution

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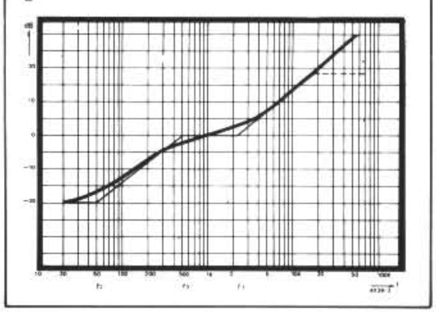

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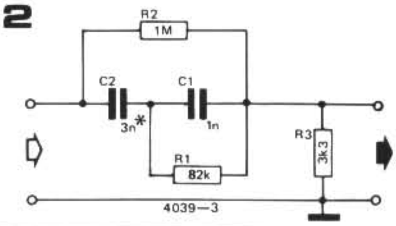

Performance characteristics of the weighting network. Noise and distortion levels will in practice be those of the LF oscillator in use.

Maximum amplitude error with 1% components	± 0,2 dB
Maximum amplitude error with 5% components	± 0.9 dB

work involved in accurately measuring the amplitude response (RIAA or IEC curve), overdrive margin, distortion, signal-to-noise ratio and hum level. The weighting network described here greatly simplifies the above-mentioned measurements. Despite its simplicity, using only five components, it will deliver a measurement signal that is within 0.2 dB of the standard RIAA cutting-curve. This should make it just about the smallest professional test instrument ever described . . .

to both problems should now be obvious: insert a weighting network having the amplitude-frequency response of figure 1 between the constant-voltage oscillator and the preamplifier under test. A suitable network is shown in figure 2. ◼

Figure 1. The IEC/RIAA weighting curve used during disc cutting. The 'recip-RIAA' network also produces this curve.

Figure 2. Circuit diagram of the network. C2 can be made up by parallel connection of twice 1.5 nF (or 2.2 nF plus 820 pF).

Figure 3. PC board and component layout for the network (EPS 4039).

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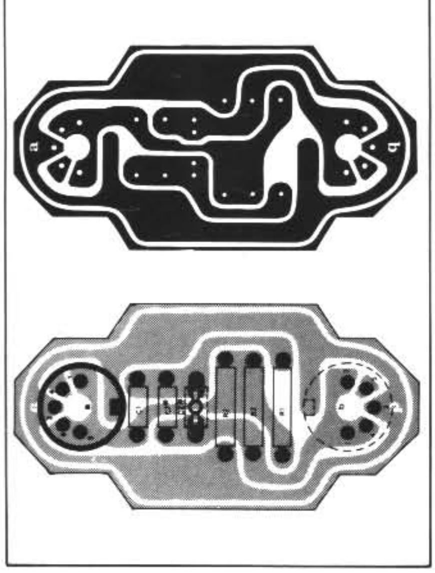
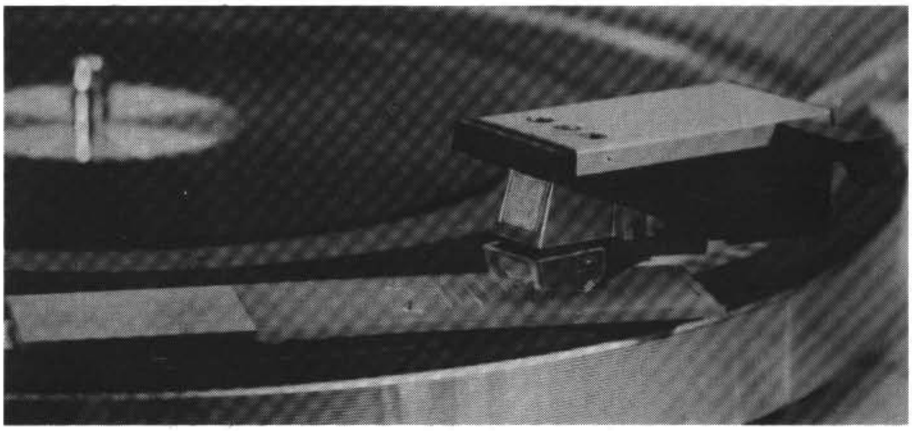


Signal-to-noise ratio	80 ... 120 dB
Distortion (with film resistors)	below noise
Oscillator output voltage for routine testing (0 dB = ± 3.5 mV at 1 kHz)	100 mV
Oscillator output voltage for overdrive test (+26 dB)	2 V

Stylus balance

Correct setting of stylus tracking force is of utmost importance – certainly for modern 'featherweight' cartridges. The gauge that is built in to many modern record players is not always reliable, so a double-check by means of a separate balance is often advisable.



The 'ideal' tracking force for most modern cartridges is somewhere in the 0.75 . . . 3 gram range.

Most manufacturers specify the minimum and maximum permissable tracking force for their cartridges. In practice, the best value usually proves to be just under the specified maximum. It is perhaps worthy of note that the danger of damage to the record is greater if the tracking force is too low than if it is too high – within moderation, of course! As a rule of thumb, the maximum for dynamic cartridges with an elliptical stylus is about 1.5 g, whereas the maximum with a spherical stylus will be about 3 g. From the above it will be obvious that a useful measuring range for a stylus balance would be 0.75 . . . 4 grams.

The p.s.b.

The simplest type of measuring instrument for tracking force is a balance – and it can also be one of the most accurate types.

An easy way of making such a balance is to use epoxy printed circuit board material. Computer aided design has resulted in the end product shown in figure 1: the printed stylus balance or p.s.b.

Round-headed furniture tacks, rivets or the like can be used as pivots. These are pushed through the holes until the heads lie flush against the back of the board. Due care should be taken at this stage: the calibration accuracy depends on the position of the pivots, and any sharp edges (such as deep scratches) can affect the freedom of movement.

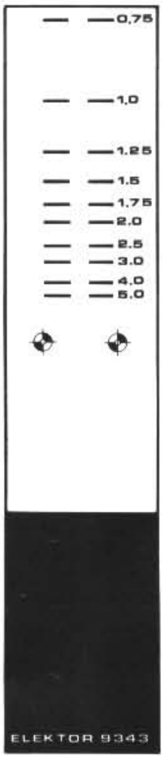
The calibration depends on the mass per unit area of the material, of course; the scale shown is accurate for the boards supplied by the Elektor p.c. board service (EPS 9343).

How to use it

The balance is placed on the turntable so that it pivots on the round heads of the tacks (see photo). The stylus is now gently lowered onto the balance, and by sliding it up or down along the open track between the calibration marks (rotate the turntable a fraction) the position can be found where the whole set-up is in equilibrium. The tracking force can now be read off.

For the highest degree of accuracy it is advisable to set the anti-skating compensation at '0', and to level the record-player. The latter is always a good idea, anyway, in the interest of minimum wow. ◼

1



miniature amplifier

For the younger constructor with limited funds it is necessary to be very cost-conscious when designing circuits. This circuit for a simple record player amplifier fulfils these requirements. The circuit will operate from a 4.5 V battery and can be used to amplify the output of a crystal pickup to drive a small loudspeaker or headphones. The circuit is not outstanding for its power or quality, but it is simple and reliable.

The input and driver stages T1 and T2 operate as voltage amplifiers. The output stage, T3 and T4, operates in class B to achieve long battery life. D.C. feedback is provided by means of R3 and A.C. feedback by means of R3, R4 and C2. This defines the gain, stabilises the operating point and increases the input impedance.

The biassing of T1 is critical and the values for R1 and R2 must be adhered to. Should the circuit fail to operate correctly the D.C. conditions may be checked at the base of T3 and T4 and the junction of R6 and R7.

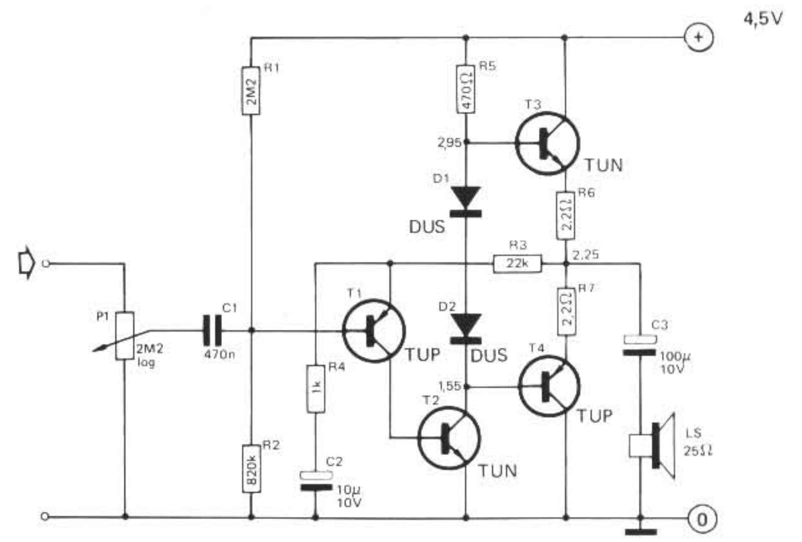
If 25 ohm loudspeakers are difficult to obtain, then 8 or 15 ohm types may be used instead. In that case R6 and R7 should be replaced by wire links.

As can be seen from figure 2 the p.c. board is extremely miniature and finding space in the record player cabinet should be no problem. To improve loudspeaker efficiency the loudspeaker cabinet should be as large as possible.

Figure 1. The very simple amplifier circuit.

Figure 2. Layout of match-box size printed-circuit board.

1



Input impedance $Z_1 \geqslant 600$ k
Input sensitivity v_i = 200 mV (r.m.s.)
Output power (with 25 Ω) P = 50 mW.

Parts list.

Resistors:
R1 = 2M2
R2 = 820 k
R9 = 22 k
R4 = 1 k
R5 = 470 Ω

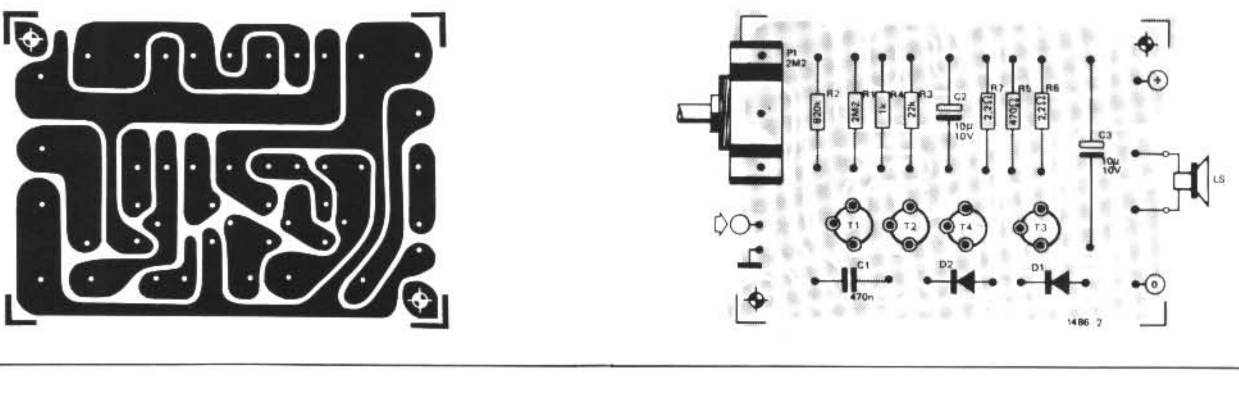
R6 = 2.2 Ω
R7 = 2.2 Ω
P1 = 2M2 log

Capacitors:
C1 = 470 n
C2 = 10 μ/10 V
C3 = 100 μ/10 V

Semiconductors:
T1,T4 = TUP
T2,T3 = TUN
D1,D2 = DUS

Sundries:
Torch battery 4.5 V
Loudspeaker 25 Ω

2



mos clock 5314

The 'brain' in the digital clock described in this article is the clock-IC MM5314, which needs only a few external components. The time of day is indicated by seven-segment Ga-As displays, which are now offered at quite agreeable prices. Another attractive feature is that if no seconds reading is included in the design, a considerable saving can be made, whilst seconds indication can always be added at a later stage.

The clock-IC

The clock integrated circuit type MM5314 is designed to indicate the time in hours, minutes and seconds with the aid of seven-segment displays. In contrast to the MM5313 it has no BCD output. Consequently, it is smaller (DIL 24 pins), has a simpler construction, and, what is perhaps even more important, is a lot cheaper. However, as appears from the circuit diagram of the MM5314 (figure 1), all the components needed for building a clock are available.

The IC receives its clock pulse from the mains, and can be used for 50 Hz or 60 Hz drive. The supply voltage may vary from 8 V to 17 V and need not be stabilized. If not connected, all drive inputs are at '1' level because resistors are incorporated which connect them to the plus pole of the supply voltage.

As regards the clock design, the IC offers the choice of various possibilities that depend only on a certain logic state of the drive input concerned.

It is possible, for instance, to choose between a 24-hour and a 12-hour cycle. With the 12-hour cycle the leading zero indication is automatically suppressed, which saves a lot of power. If in addition no seconds reading is required, two seven-segment displays and two transistors can be omitted, which gives a considerable saving. By means of the input 'strobe', read-out can be suppressed, and there are, of course, control inputs for retarding or advancing the clock. The clock can also be stopped for correct time setting. The table gives all possible settings of the control inputs. Figure 2a shows a top view of the pins of the MM5314 integrated circuit.

Operation

In the overall circuit of the IC two main sections can be distinguished:

a. the counter with corresponding circuits

b. the circuits for decoding and driving the displays (surrounded by the dashed line in figure 1).

Pulses to drive the counter are obtained from half cycles of the mains supply. The pulse shaper at the input of the counter changes the sine-waves into square waves by means of a Schmitt trigger. This trigger has a hysteresis of about 5 V. Depending on the logic state at pin 11 of the IC, the pulse signal is divided by 50 or 60, so that a signal of 1 Hz becomes available for the next divider. In the next three stages of the counter the pulse signal is divided into minutes and 12 or 24 hours, depending on the cycle chosen, and determined by the logic state of pin 10.

Via the gates of the individual stages of the counter the clock can be set correctly. If pin 14 of the IC is at '0', the clock will run at the rate of 1 minute per second. If pin 15 is at '0', the hours will run at the rate of 1 hour per second. When pin 13 is at '0', the clock is stopped. If a 12-hour cycle is chosen, the leading zero is suppressed by a special circuit in the IC.

Counter read-out and display drive are achieved with a multiplex technique. The multiplexer senses the various counter positions successively in the rhythm of a multiplex frequency, and passes the value found to a decoder, and from there to an output memory (ROM-Read Only Memory). The multiplex frequency can be varied by means of a simple RC network connected to pin 23. The multiplex oscillator is followed by a divider that, depending on the logic state of pin 24, produces four- or six-digit drive pulses (with or without seconds, respectively). Using the multiplex technique implies that the displays are not driven in parallel, but in series. Parallel drive means that all counter positions can be read out simultaneously. To that end the counter reading of each decade is, at a certain moment, fed to a memory corresponding to each decade. The information thus stored drives the displays of the counter readings via a decoder. This happens simultaneously for all decades; hence the term parallel drive. Multiplex technique, however, means that all counter readings are scanned quickly in successive order and are fed in the same order to an output memory (ROM), which for this IC is programmed for seven-segment displays. At the same time that the counters are read, each corresponding display receives the supply voltage via the drive logic of the block marked 'Digit Enable'. This means that, with this clock, the counters can be read 1 out of 4 if a four-digit display is used, or 1 out of 6 for a six-digit display; the logic state of pin 24 determines the display mode. If, for instance, the one-second counter is read, the one-second display receives supply voltage via 'Digit Enable', and the reading of this decade becomes visible. Corresponding segments of each display are interconnected, but only the particular segments of a display that receive a voltage will light up. In spite of the fact that series drive is used, visual read-out remains constant, provided the multiplex frequency is higher than about 100 Hz. In the MM5314 the multiplex frequency can be chosen up to 60 kHz. If the read-out is suppressed via pin 1 ('strobe') of the IC, the clock will continue to run normally. Thanks to this feature it is quite easy to build an emergency supply.

The circuit

The complete circuit in figure 3 shows that apart from the MM5314 only few components are needed to build a complete clock, Perhaps somewhat unusually, the circuit description starts with the supply, because it is from there that the counter pulses are derived. Since the supply voltage for the IC need not be stabilized, the source has been kept as simple as possible. The d.c. supply voltage may be anything between 8 V and 17 V.

The half cycles of the 50 Hz mains are fed to the pulse input via a decoupling network R22/C3. This input is protected against overloading by means of diode D1.

The RC network (R23/C4), connected to pin 23 of the IC, determines the multiplex frequency which, for the given values, is about 10 kHz, Because the integrated circuit cannot provide sufficient current to drive the seven-segment display simple buffer stages are required. These use normal TUN's and are connected between pins 3 to 9 and the display segments. The collector resistors provide current limiting for the segments, so their values determine the luminous intensity of the displays. The minimum permissible value for these resistors is 330 Ω ($+V_b$ = 17 V), in practice 470 Ω gave satisfactory results for all supply voltages. A lower value produced no noticeable increase in luminous intensity, so that in fact only the life of the display is then unnecessarily shortened.

Buffer transistors, acting as switches, are also connected between the 'Digit-Enable' outputs and the anodes of the displays. These switches connect the

Table

function	state*	pin
stop	'0'	13
slow adjustment	'0'	14
quick adjustment	'0'	15
mains frequency 50 Hz	'1'	11
mains frequency 60 Hz	'0'	11
12-hour cycle	'0'	10
24-hour cycle	'1'	10
with seconds	'0'	24
without seconds	'1'	24
strobe	'0'	1

*) An unconnected input is at state '1' because within the IC these inputs are connected to the plus of the supply voltage via resistors.

1

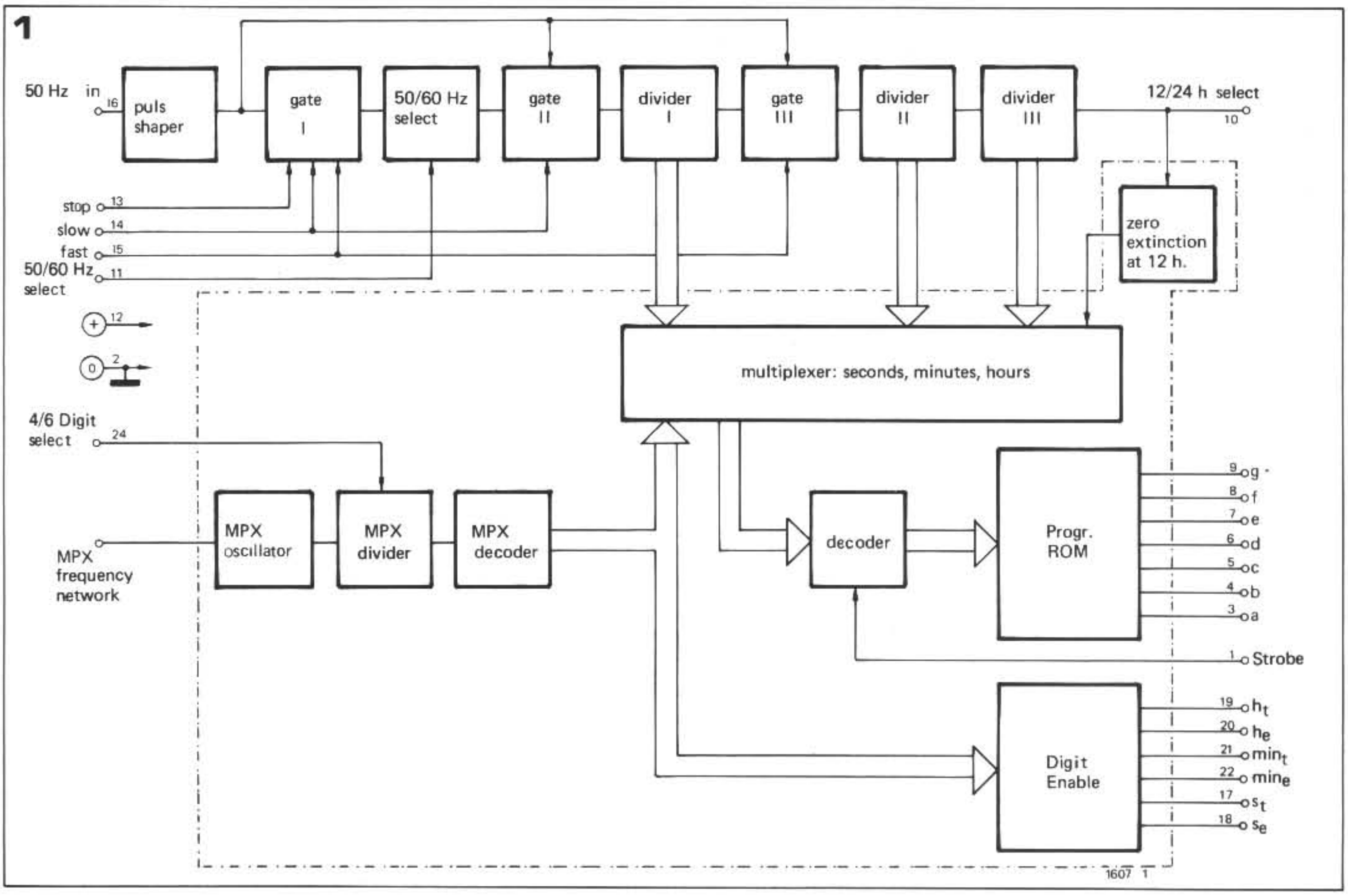


Figure 1. Block diagram of the MM5314 integrated circuit. From this it is clear that the entire clock, except the supply and drive for the displays, is incorporated in this IC.

2

a

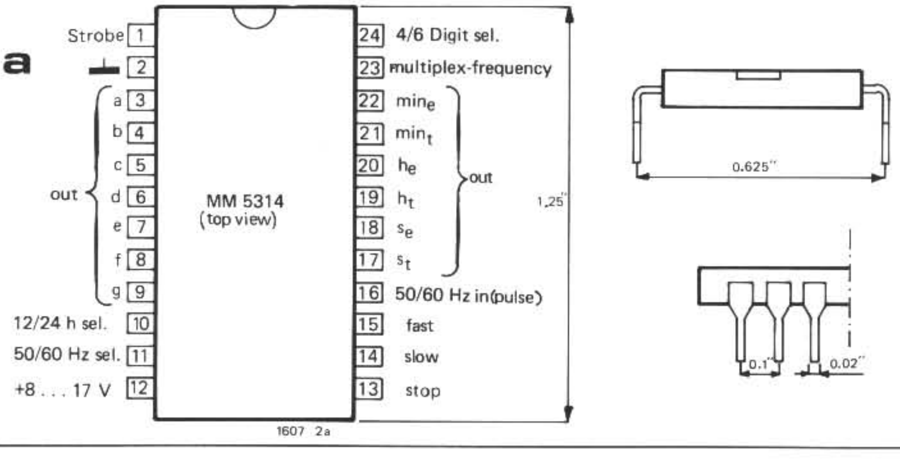


Figure 2a. The pins of the IC seen from the top.

b

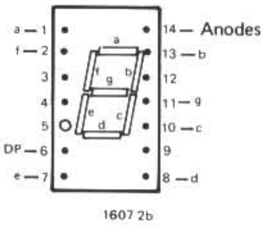
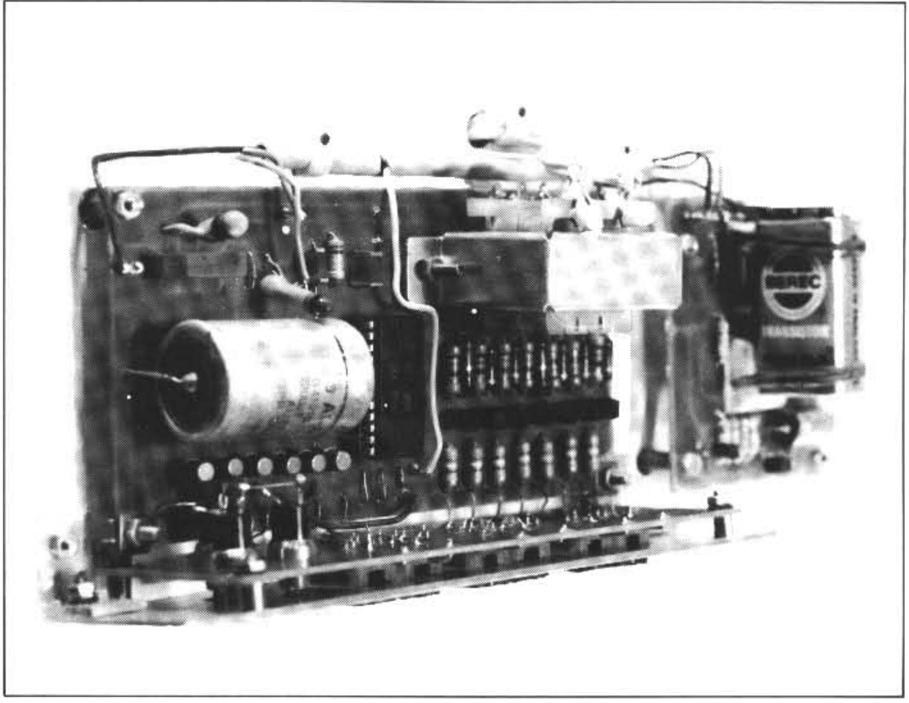


Figure 2b. Pin details of the Opcoa red GaP seven-segment display type SLA1. With most other types of seven-segment displays separate anodes are also connected to pins 3 and 9; hence, an extra connection is needed between these pins and pin 14.

second-, minute- and hour displays to the supply voltage at the correct moment. The switching transistors used here are TUPs.
The circuit is mounted on two printed circuit boards: one for the displays, and one for the actual clock circuit with mains supply.

Printed circuit boards

Figure 4 shows the printed circuit board, and figure 5 the component layout for the mains-fed clock circuit. The boards are quite small, so that the whole unit can be housed in a small attractive cabinet. So much space has been reserved on the board for the supply transformer and electrolytic capacitor C2 that, if necessary, fairly large types can be used. All terminals and controls (50/60 Hz selection, strobe, etc.) are placed in a row on one side of the board, directly opposite the terminals they are connected to on the display board, which is shown in figure 6. This display



3

Parts list

Resistors:
$R_1 \ldots R_7$ = 10 k
$R_8 \ldots R_{14}$ = 100 k
$R_{15} \ldots R_{21}$ = 470 Ω
R_{22}, R_{23} = 100 k

Capacitors:
C_1 = 5n6
R_2 = 2200 μ/25 V
C_3 = 10 n
C_4 = 22 n
C_5 = 47 n

Various:
Tr = mains trafo, 8 . . . 12V/250 mA
$S_1 \ldots S_3$ = miniature push-button, SPST
IC-socket (24 pin DIL)

Semiconductors:
IC = MM5314
$T_1 \ldots T_7$ = TUN
$T_8 \ldots T_{13}$ = TUP
D_1 = DUS
B = bridge rectifier B30C500, BY 164 etc.
Displays = Opcoa SLA 1, Monsanto MAN 1, MAN 7 and MAN 10, Hewlett Packard 5082-7730, Litronix Data Lit 707

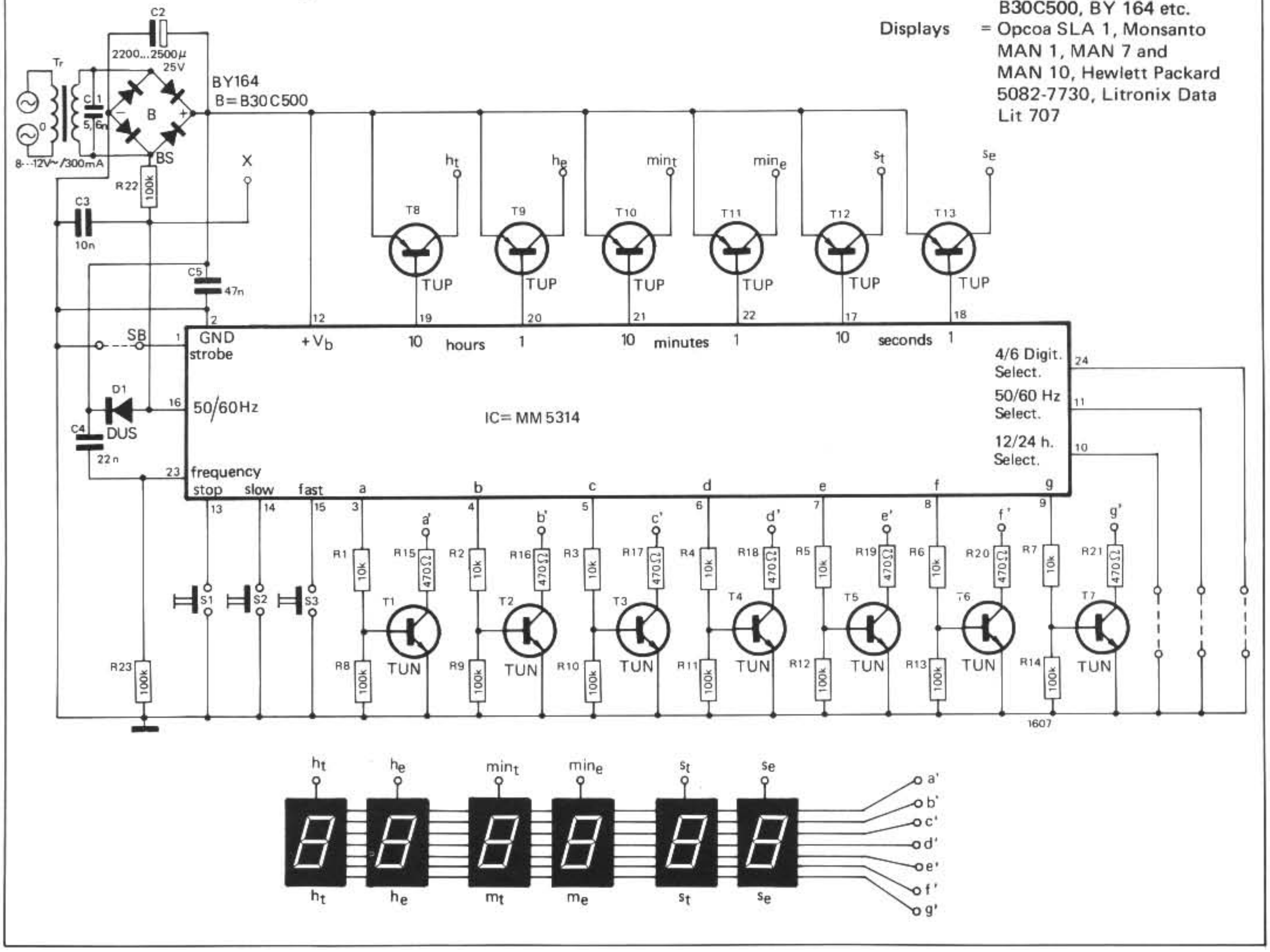


Figure 3. The total circuit complete with mains supply. If instead of TUNs, quality transistors are used for T1...T7 (e.g. BC107), the resistors R8...R14 can be omitted.

Figure 4. The printed circuit board of the clock circuit with mains supply. The pins are positioned so that only very short connections are needed between clock and display circuit boards.

Figure 5. Component lay-out for the clock circuit. There is sufficient space for almost any type of transformer. Even a 40 V electrolytic capacitor could be accommodated on the circuit board.

board holds the displays and small push buttons for 'stop', 'slow' and 'fast'.

Displays

The display board (figure 6) is mounted behind the front plate of the cabinet. Instead of the seven-segment LED displays used here (the Opcoa SLA1), types MAN1, MAN7 and MAN10 of Monsanto, T6302 of Texas, 5082 and 7730 of Hewlett Packard or Data Lit of Litronix can be used. Some of these even have two LEDs per segment, which gives a greater intensity at a slightly lower current consumption. Unfortunately, there are many displays where not all anodes are connected to pin 14, but have separate anodes connected to pins 3 and 9. The pins 3 and 9 (at the bottom of the displays concerned) must then be bent completely inward and connected to pin 14.

With or without seconds

If the 'seconds' indication is not used the expense of two displays, two sockets and two transistors can be saved. In this case there is no connection between pin 24 and earth. Since the board is designed for six displays, two more can always be added at a later time without much trouble.

Connection between the boards

In total (including the seconds) there are 13 control connections between the clock and the display circuit boards. The six pins of Digit Enable (h_t, h_e, m_t, m_e, s_t, s_e) are connected to the corresponding terminals on the display board. Furthermore, the terminals a to g of the clock circuit are connected to the same terminals on the display board. Three other connections run to the three small push-buttons for setting the clock. One side of each button is connected to the supply common.

By means of time signals on the radio, TV, or telephone service, the clock can be started properly and quite accurately. With the buttons 'fast' and 'slow' the clock is pre-set before the time signal

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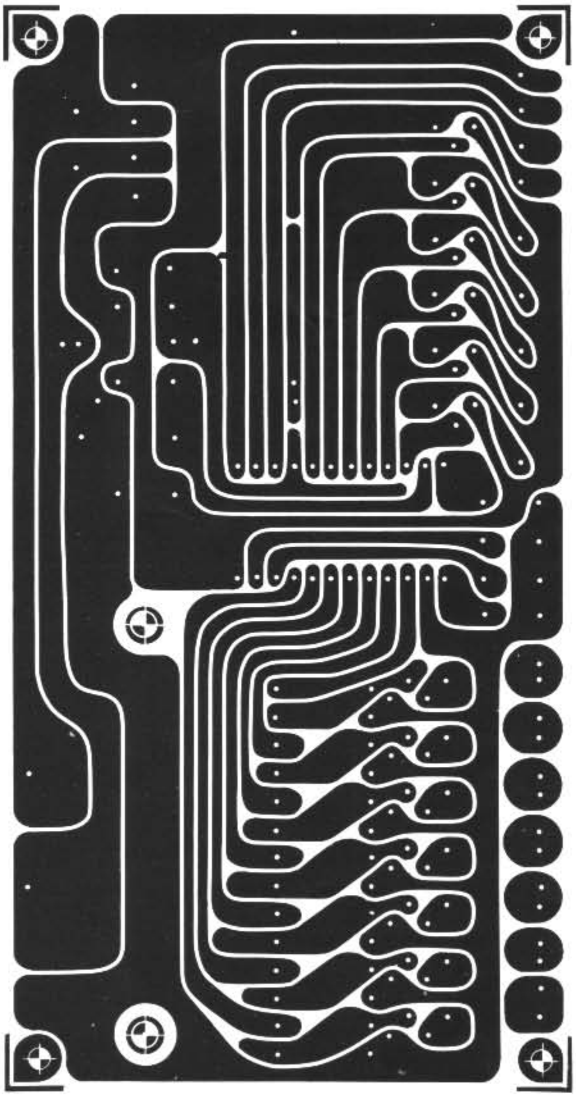

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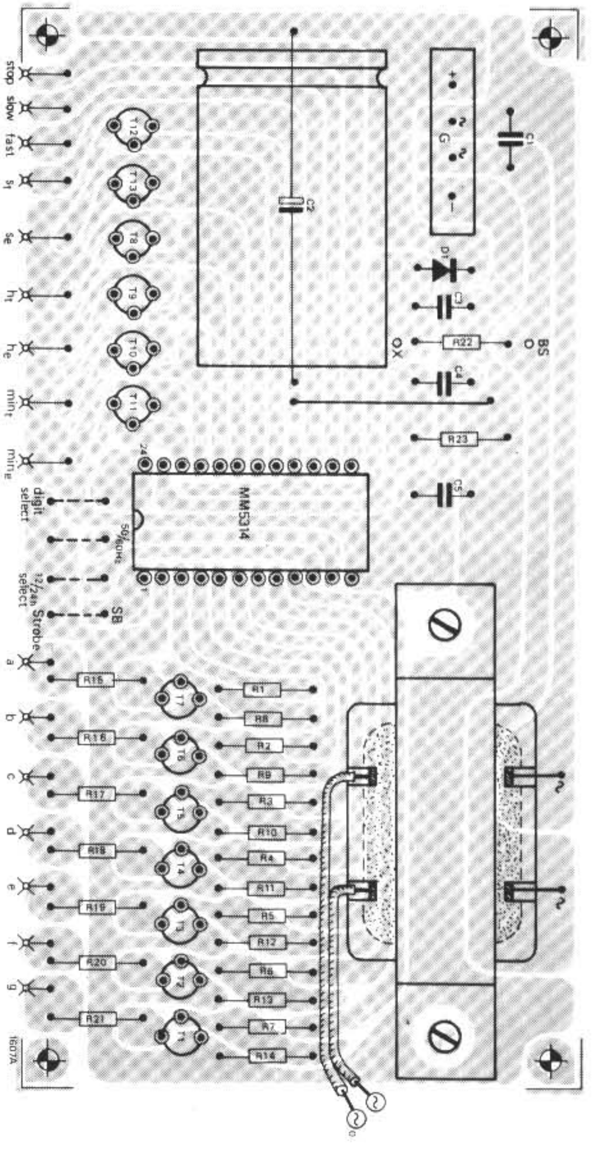
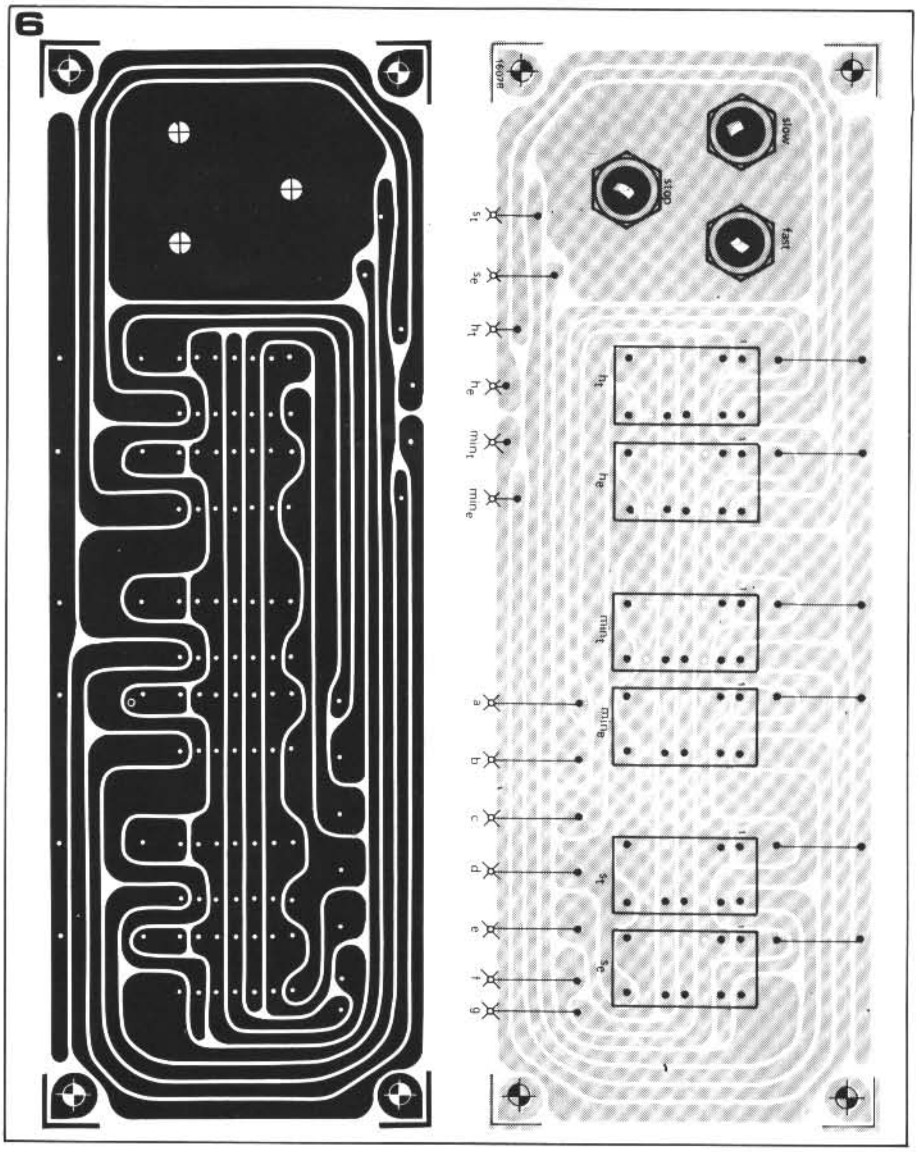


Figure 6. The display circuit board. The small buttons for setting the clock are at the front.



comes, and the button 'stop' is released the moment the signal sounds. The front of the cabinet must have openings for the four or six displays which can be mounted behind perspex, for instance.

Further developments

In Elektor laboratories the following additional units have been developed for the clock:

- crystal-controlled time base with only one IC; current consumption complete with oscillator: about 90 μA.
- emergency supply in case the mains supply fails.

These extensions are discussed elsewhere in this book. The points marked SB, BX and X in figure 3 and in the component lay-out are for use with these units.

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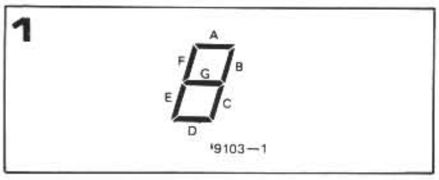
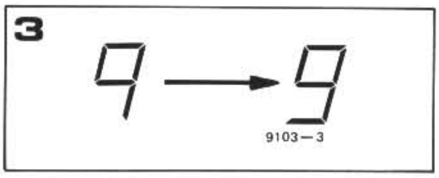
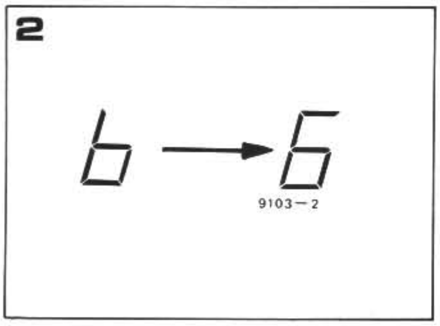
improved 7-segment for MOS-clocks

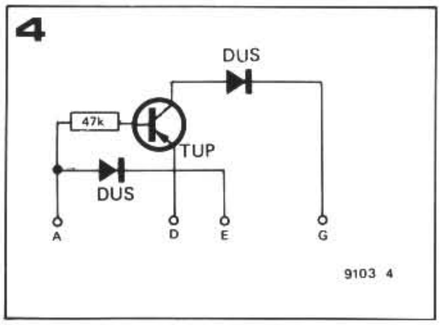
The idea is to add an extra stroke at the top of a six and at the bottom of a nine (Figures 2 and 3).

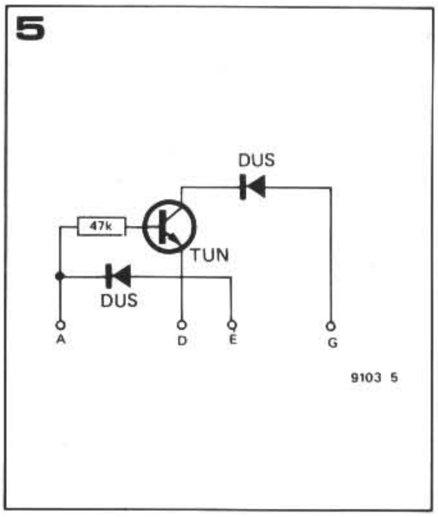
The circuit in figure 4 can be used with common-anode displays, as in the MOS-clock. The points A, D, E and G are connected to the collectors of the corresponding segment-drive transistors (T1, T4, T5 and T7 in the MOS-clock). For common-cathode displays the circuit of figure 5 can be used.



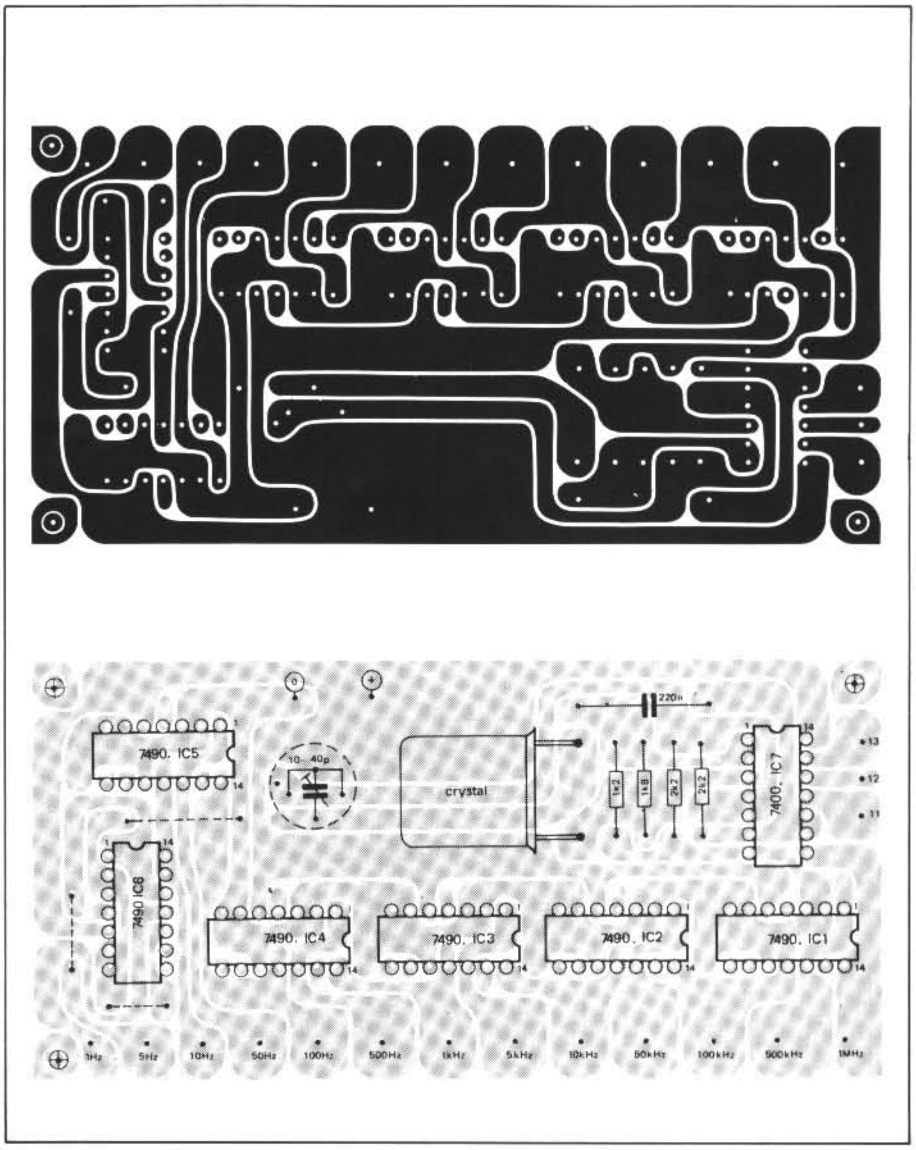






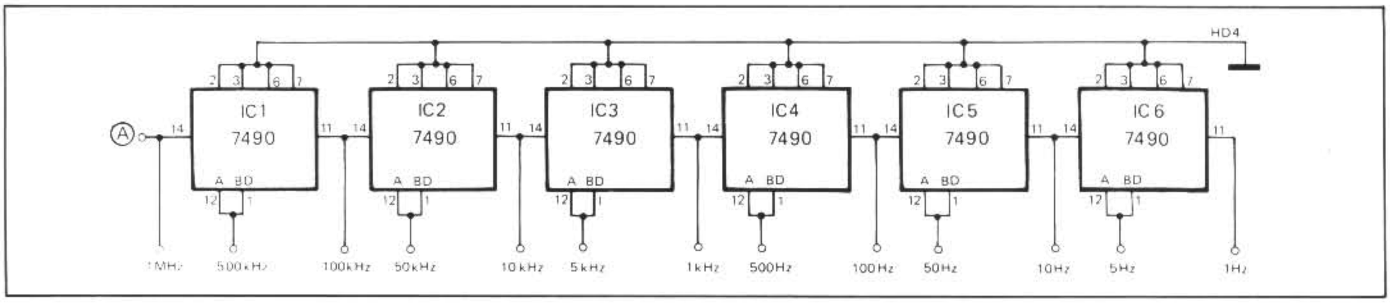


universal frequency reference



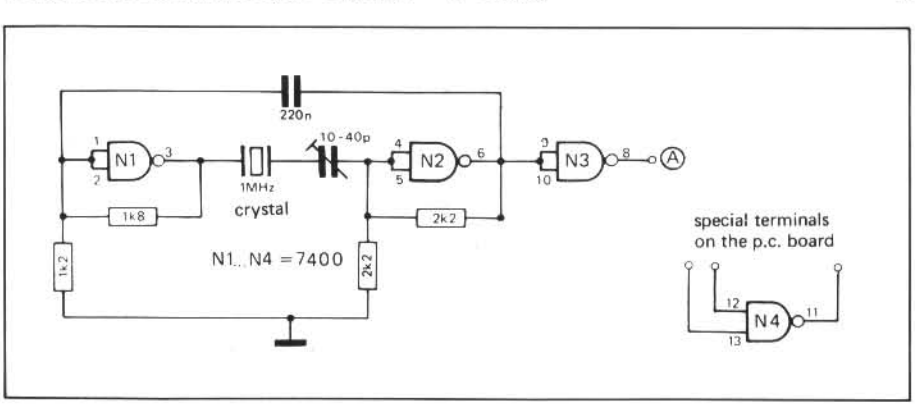
This circuit claims nothing in the way of originality, but is simply a useful, general-purpose board that can be used in many frequency and time measuring applications. It is particularly suitable for use as a gate pulse generator in frequency counters.

The heart of the system is a 1 MHz crystal oscillator based on two NAND-gates. The output of this oscillator is buffered by a third NAND-gate and the frequency is then divided down by a series of 7490 decade counters. These consist of a divide-by-2 stage followed by a divide-by-5 stage, which means that in addition to dividing the reference frequency down to 1 Hz in decades, outputs of 500 kHz down to 5 Hz are also available. These outputs are particularly useful where gate pulses for frequency counters are required. For example, the 5 Hz output will provide positive pulses of 100 ms width, so if the frequency of a 10 MHz signal were being measured a gate pulse this long would let through 1,000,000 cycles of the signal to the counter, giving a display of 1000000. On the other hand, for period measurements the 1 Hz to 1 MHz outputs are more useful. For example, when measuring a one second period, 1,000,000 cycles of the 1 MHz output can be counted, giving a display of 1000000.



The p.c. board layout is quite compact and well laid out. The outputs are available along the lower edge of the board in the diagram. There is one spare NAND-gate in the package used for the oscillator, and this may be used as the gate in frequency counter applications. The connections to it are brought out at the top right corner of the board.

The oscillator frequency may be trimmed to exactly 1 MHz by the trimmer capacitor. The best method of doing this is to use an oscilloscope to compare the 100 kHz output with the 200 kHz Droitwich transmissions, using Lissajous figures. The trimmer should, of course, be adjusted until the Lissajous figure apparently ceases to rotate. ◆



steam train

Many owners of model railways want their 'world of trains' to be as realistic as possible. A means of imitating the sound of a real steam train is, therefore, more than welcome. This article describes a simple method of building an electronic circuit of few components that will produce the required sound. To add even more authenticity, the rhythm of the steam train sound is regulated automatically and is practically proportional to the speed of the train.

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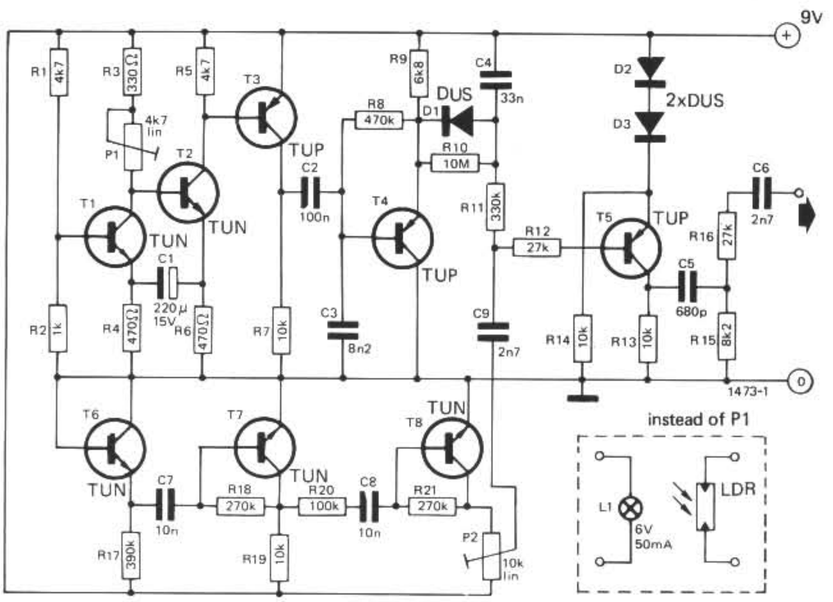


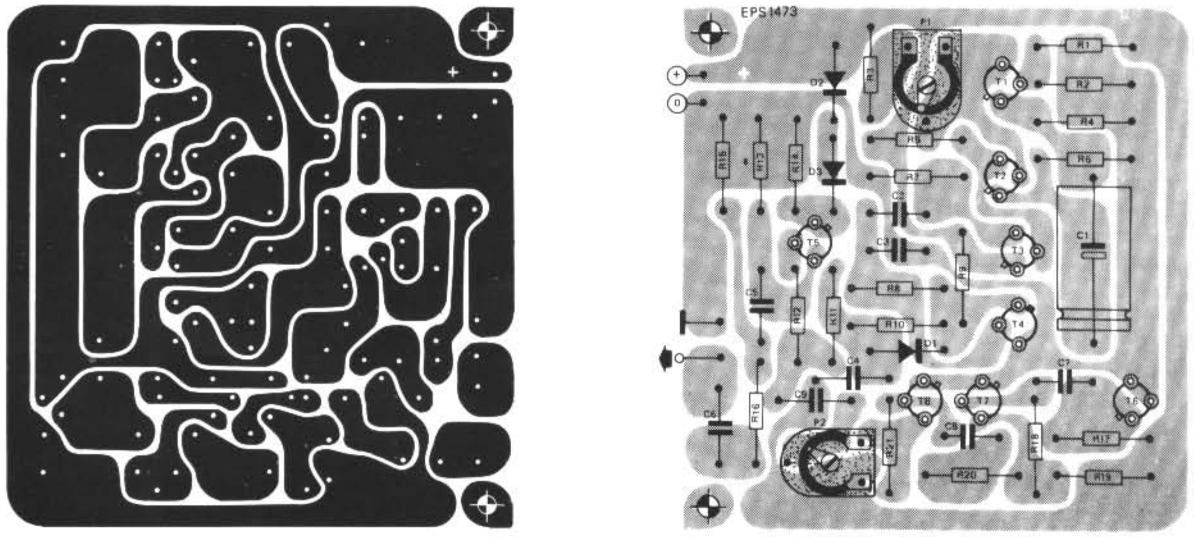
Parts list

Resistors:
R_1 = 4k7
R_2 = 1 k
R_3 = 330 Ω
R_4 = 470 Ω
R_5 = 4k7
R_6 = 470 Ω
R_7 = 10 k
R_8 = 470 k
R_9 = 6k8
R_{10} = 10 M
R_{11} = 330 k
R_{12} = 27 k
R_{13} = 10 k
R_{14} = 10 k
R_{15} = 8k2
R_{16} = 27 k
R_{17} = 390 k
R_{18} = 270 k
R_{19} = 10 k
R_{20} = 100 k
R_{21} = 270 k
P_1 = 4k7 lin.
P_2 = 10 k, trimmer

Capacitors:
C_1 = 220 μ, 15 V
C_2 = 100 n
C_3 = 8n2
C_4 = 33 n
C_5 = 680 p
C_6 = 2n7
C_7 = 10 n
C_8 = 10 n
C_9 = 2n7

Semiconductors:
T_1, T_2, T_6, T_7, T_8 = TUN
T_3, T_4, T_5 = TUP
D1, D2, D3 = DUS

3



The circuit

Figure 1 shows the complete circuit diagram. The sound of a real engine is produced by the regular escape of waste steam. This hissing sound is produced electronically by a noise generator. The rapid increase and slow fading of the noise as well as its rhythm, is controlled by an astable multivibrator and a pulse shaper. The output of the noise generator T6 is amplified by transistors T7 and T8. The amount of noise, or noise level, can be adjusted by means of potentiometer P2. The transistors T1 and T2 form the astable multivibrator which produces a square wave.

The rhythm of the steam sound can be varied by means of P1. By coupling the spindle of this potentiometer to the speed control on the supply transformer for the locomotive, the rhythm of the steam sound is automatically controlled by the speed of the train. Should this arrangement be too difficult, the potentiometer can be replaced by a light-dependent resistor (LDR); practically any type of LDR will do. A suitable lamp is then connected in parallel with the power supply for the train and placed with the LDR in an opaque envelope to ensure that other light sources, such as room lighting, have no effect.

The light intensity now depends on the speed of the train; this controls the value of the LDR and this adjusts the rhythm of the sound to match the speed. To ensure satisfactory control, it may be necessary to try several lamps of different wattage. The capacitors C2, C3 and C4 convert the square wave produced by the astable multivibrator into a certain pulse shape. This pulse drives transistor T5 quickly into conduction, but cuts it off again at a much slower rate. For a short time, transistor T5 then feeds the amplified noise signal to the output while amplifying it even more, after which the amplification is reduced slowly. The output signal can be further amplified by means of an external amplifier or radio set.

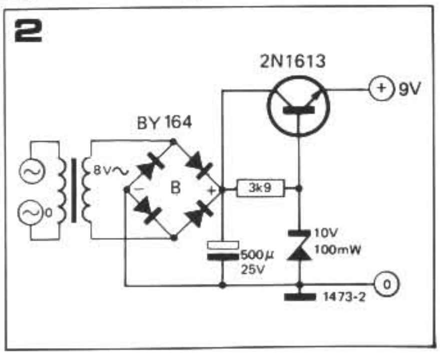
The supply

The circuit can be fed from a 9 V battery. Figure 2 shows the circuit for a mains supply.

Figure 1. The electronic steam train circuit.

Figure 2. Circuit diagram for power supply.

2



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steam whistle

Many model railways still run on 'steam'. For greater realism the steam locomotives are nowadays often fitted with an artificial smoke device. They become even more realistic when an imitation steam whistle is also provided.

1

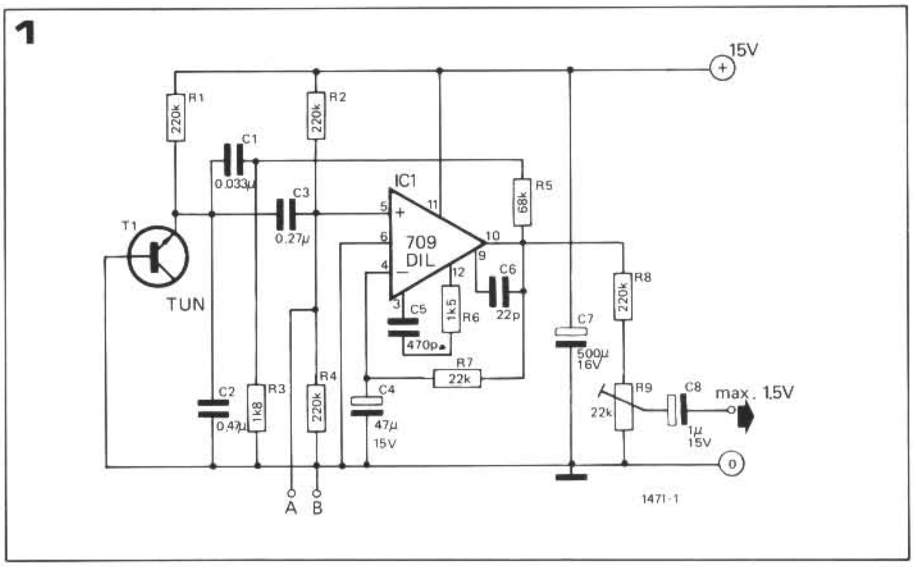


Figure 1. The circuit diagram of the steam whistle. Note the unusual feedback circuit.

In general, electronic imitation of sounds is not so easily done. Analysis of a specific sound by looking at an oscilloscope display, or, better still, with the aid of a spectrum analyser, will make clear just how complicated that sound can be. The spectrum analyser is the clearer, because it displays the various frequency components with their relative amplitudes. But even given sufficient information about the composition of a sound, its electronic imitation is still no pushover. An accurate imitation usually requires a 'truckload' of circuitry.

An acceptable imitation, however, can be achieved with less complication. The problem in this case is nonetheless the same, how to dream up a suitable circuit. Any attempt to seriously calculate component values is futile, particularly when the sound produced is only an approximation to the original. Then there is always the consideration that a spectrum analyser is not normally readily available, never mind a genuine working steam whistle! One is forced to the conclusion that trial and error is the only available approach.

The circuit

We already know two aspects of the circuit. A steam whistle produces a tone, so that the heart of the circuit must be an oscillator. Secondly, a steam whistle is blown – which means hiss. The circuit must therefore also contain a noise generator. This noise generator must modulate the oscillator. Experiment will determine which method of modulation is to be used. Assuming that the brute-force excitation of the original steam whistle gives rise to strong overtones, the oscillator will have to be some kind of multivibrator producing a fairly sharp-edged waveform. The selected square-wave oscillator is a 709 in a positive feedback arrangement (and including the usual compensation).

The noise-generator is a reverse-biassed base-emitter junction of an NPN transistor.

At the supply voltage of 15 V this junction operates in the breakdown region (Zener), producing plenty of noise. Resistor R1 limits the current to protect T1. Since the noise is directly injected into the oscillator feedback path, it causes an irregular frequency-modulation of the square-wave. This irregular jittering of the waveform causes the output to sound piercingly shrill – very like a real steam whistle.

The pitch of the note can be varied by changing the values of the capacitors. The influence of the noise generator is largely determined by R3. Varying R3 adjusts the shrillness of the note, but one must bear mind that it will also affect the pitch to some extent.

Keying possibilities

Due to the fact that almost any disturbance of the circuit has an influence on the pitch, it is not possible to key the whistle by electronically switching the feedback. The best approach turned out to be short-circuiting the points A and B. This disturbs the biassing of the 709, causing the oscillation to stop immediately.

This keying can be done, of course, with a push-button (break contact) – but it is much more interesting to let the locomotive switch the whistle on and off.

This can be achieved with a Light Dependent Resistor in two operating modes. The whistle sounds either when light falls upon the LDR or when the LDR is shielded. Figure 2 gives the circuits for both modes. When the whistle is to be started by illumination of the LDR, the circuit with T2 is sufficient. If the triggering is to be done by shadowing the LDR, T3 and R13 have to be added.

The board layout in figure 3 enables either arrangement to be used. In the first case, a jumper lead is required between the base and collector connections for T3.

The positioning of the LDR is very important. When a shadow is to trigger the whistle, the illumination under 'silent' conditions has to be very strong.

A real train usually gives a warning signal just before entering and leaving a tunnel. An LDR positioned under the track will arrange for the model train to automatically do the same. The same applies to a level-crossing. Here once again an LDR mounted under the track, between the sleepers, will greatly add to the realism of a model railway.

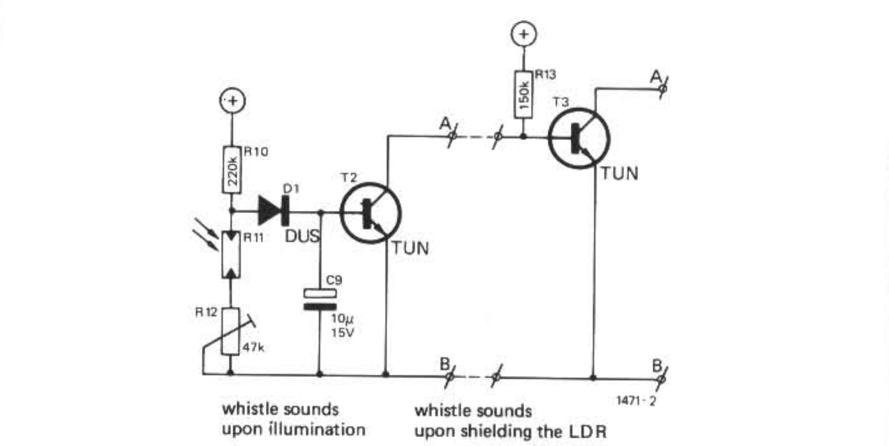
Sometimes a quite weak shadow is enough to start the circuit. Some adjustment of the sensitivity is possible with R12.

When the ambient light level in the 'playroom' is on the low side, it will be necessary to shine extra light on the LDR. The same applies to the circuit that whistles upon illumination. To start the circuit it is necessary to distinctly illuminate the LDR.

Figure 2. The optical keying switch for the steam whistle, which will respond to either illumination or shading of the LDR.

Figure 3. Printed circuit board and layout for the steam whistle with optical switch.

2



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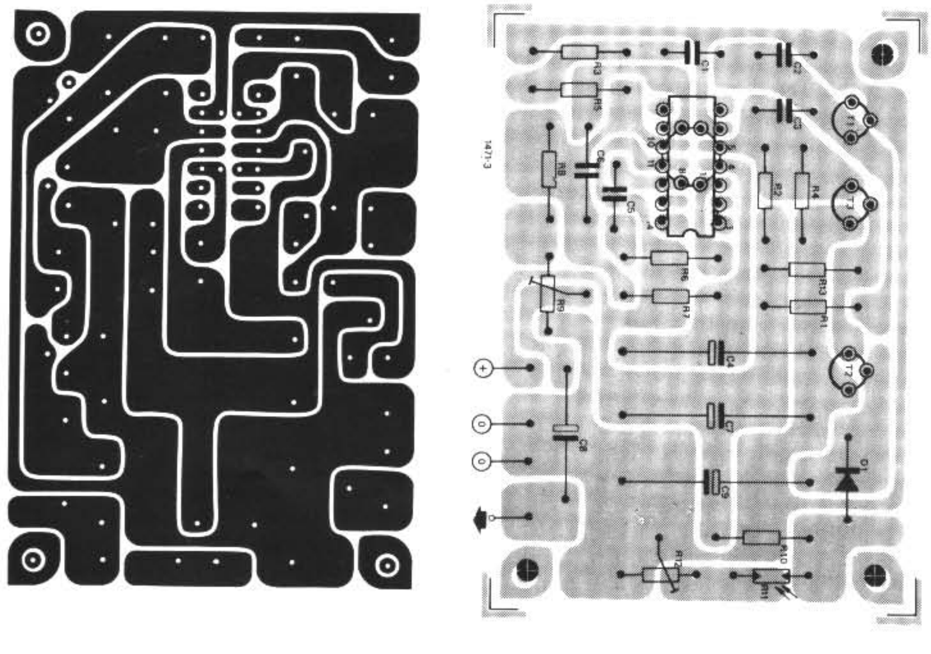


Parts list

Resistors:
R_1, R_2, R_4, R_8, R_{10} = 220 k
R_3 = 1k8
R_5 = 68 k
R_6 = 1k5
R_7 = 22 k
R_9 = 22 k, trimmer
R_{11} = LDR 03
R_{12} = 47 k, trimmer
R_{13} = 150 k

Capacitors:
C_1 = 0.033 µ
C_2 = 0.47 µ
C_3 = 0.27 µ
C_4 = 47 µ/15 V
C_5 = 470 p
C_6 = 22 p
C_7 = 500 µ, 16 V
C_8 = 1 µ, 15 V
C_9 = 10 µ, 15 V

Semiconductors:
T_1 ... T_3 = TUN
D_1 DUS
IC_1 = 709

edwin amplifier

This is a design for a high-quality 40 W audio amplifier based on an earlier 20 W design which has proved very popular on the continent. The amplifier embodies some unusual design features and the construction is problem-free due to the small amount of negative feedback employed and to the absence of quiescent current in the output stage.

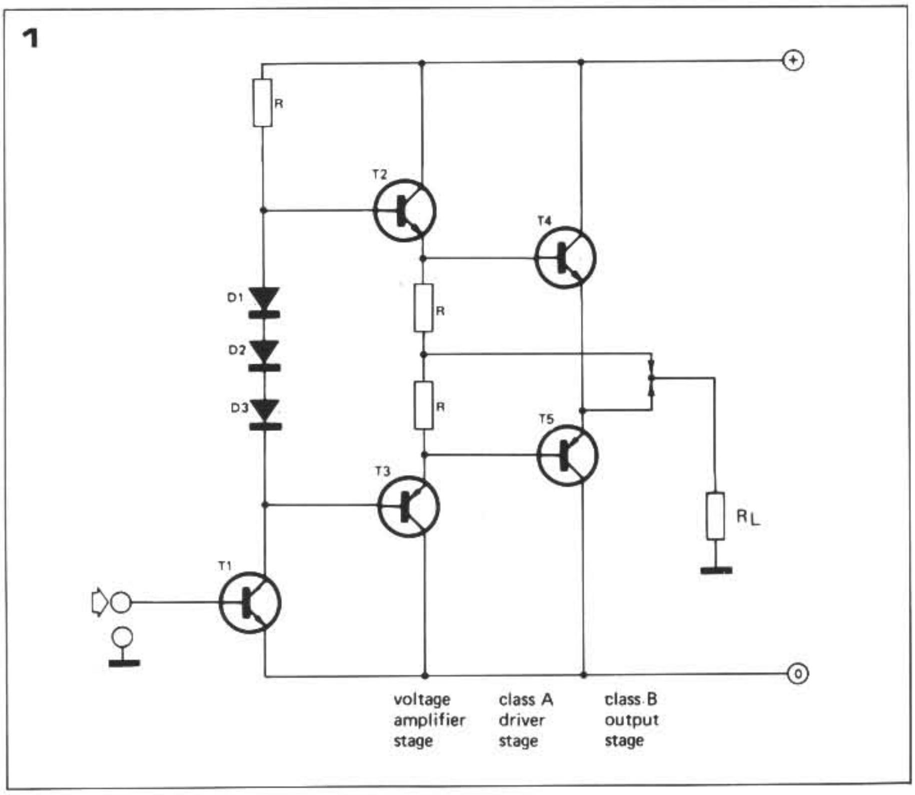
The Edwin amplifier is unusual in that it embodies two types of output stage in one amplifier. A class A output stage handles the low level signals and also serves as a driver for a class B stage which handles the larger outputs.

The principle of operation is shown in figure 1. T2 and T3 are biased on by the voltage drop across the diodes D1-D3. T2 and T3 function as a class A stage at low signal levels supplying current to the load via resistors R. As the signal is increased the voltage drop across these resistors becomes sufficient to cause T4 and T5 to conduct and the class B part of the output stage begins to operate. Crossover distortion is quite low with this type of design.

The complete circuit

As figure 2 shows, the complete amplifier circuit consists of a voltage amplifier, a class A driver stage and a class B output stage. The input stage consists of T1 and T2 in a Darlington configuration, resulting in a high input impedance. The signal passes to the base of T3 via the limiting resistor R4. T3 operates as a voltage amplifier and in its collector circuit has T4, which is connected as a simulated zener diode to provide a constant d.c. bias voltage of about 2 V across the bases of the driver transistors T7 and T8. Feedback is applied between the output and the junction of R11 and R12 to provide a high collector impedance so that true current drive is achieved. This helps to reduce crossover distortion still further so that despite the small amount of overall negative feedback and the absence of quiescent current in the output stage the distortion figures are very good.

1



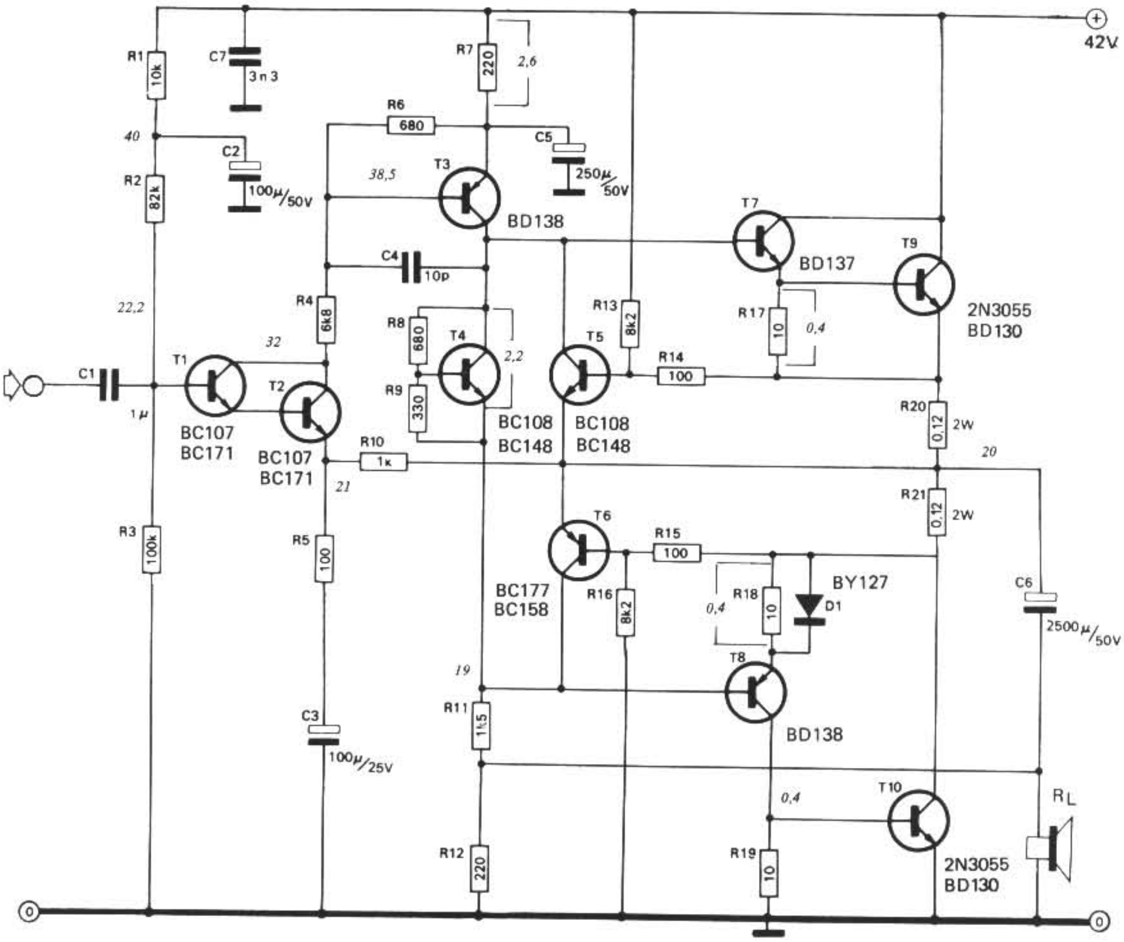
features

- output power from 10-40 W depending on power supply.
- high efficiency.
- low crossover distortion.
- short circuit proof.
- no quiescent current in the output transistors.
- output transistors and drivers need not be matched.
- unconditionally stable.

figures

- Sensitivity: ≈ 1 V (RMS).
- Input impedance: ≈ 45 kΩ.
- Distortion: 1 kHz, 30 W: 0.1%, 10 kHz, 30 W: 0.3%.
- Power bandwidth: 20 Hz – 100 kHz.
- S/N ratio: > 90 dB.

2



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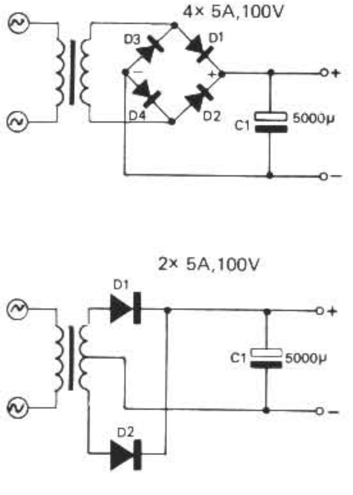


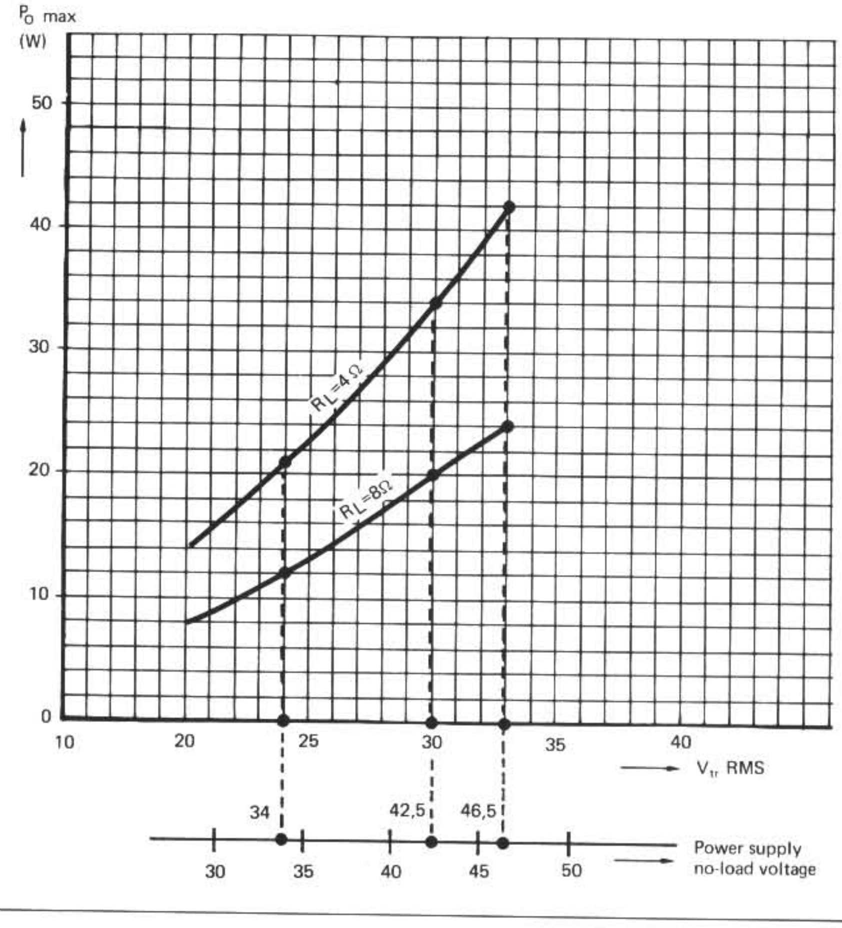
Figure 1. Basic circuit of an Edwin-type output stage.

Figure 2. Final circuit of the Edwin amplifier for output powers up to 40 W.

Figure 3. The power supply.

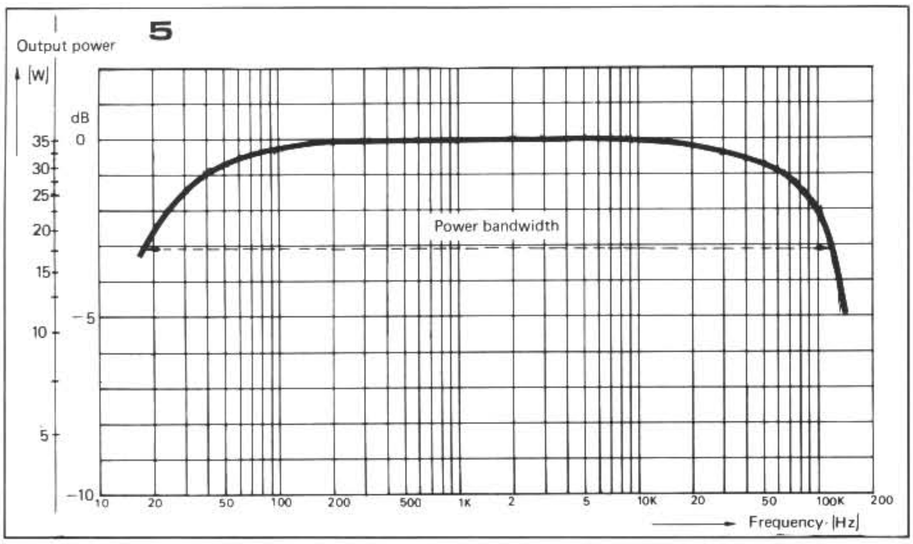
Figure 4. Graph of available output power versus transformer secondary voltage for 4 Ω and 8 Ω loads.

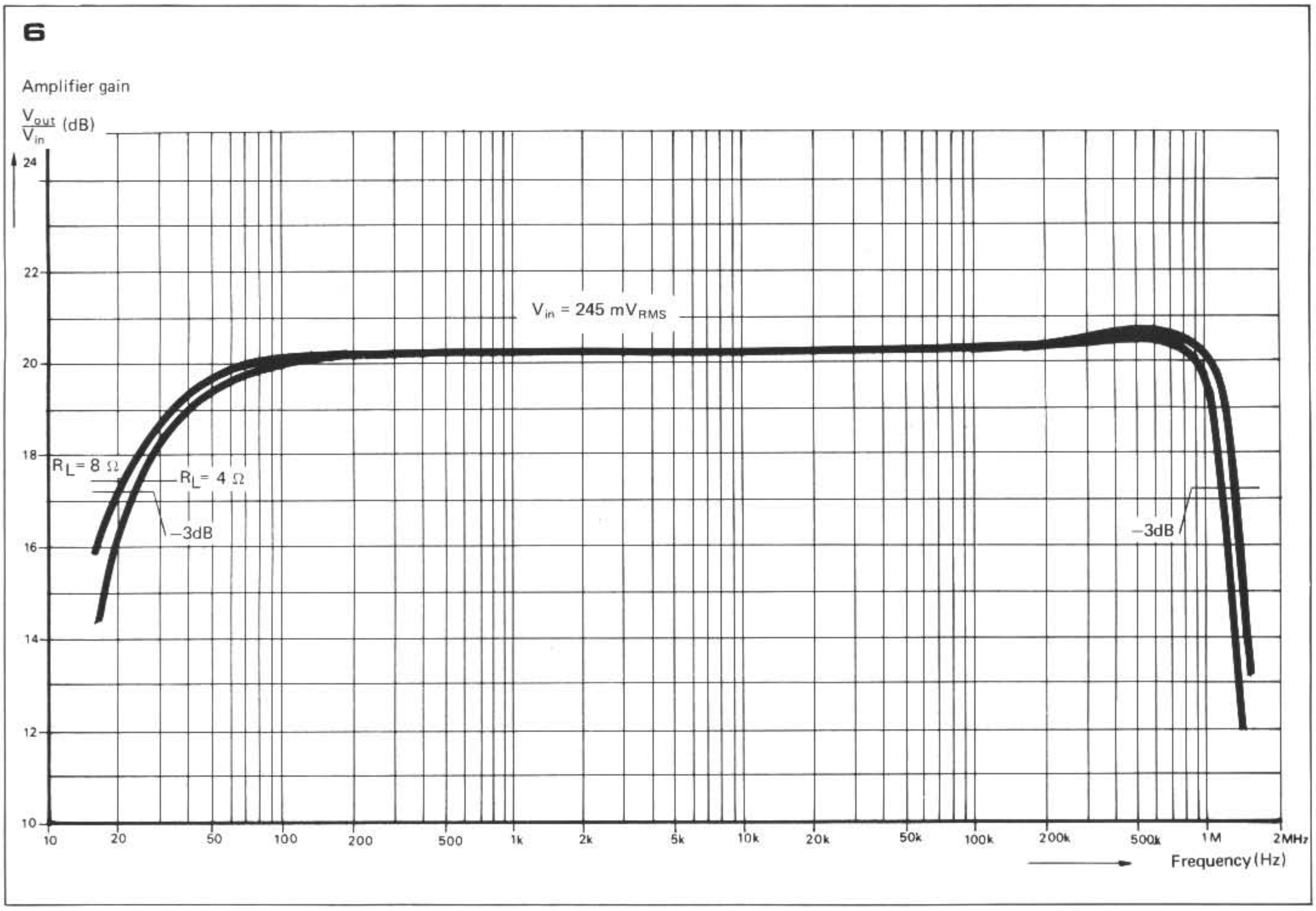
4



The output stage differs from the configuration shown in figure 1 because it comprises two NPN transistors of the same type and not a complementary pair. To maintain symmetrical operation of the output stage D1 is included across R18. This simulates the base-emitter junction which would be present across R18 if the configuration of figure 1 has been used. The values of R17, R18 and R19 are low (10 Ω) to reduce crossover distortion.

Overall negative feedback is applied from the output to the emitter of T2. The inclusion of C3 means, that 100% d.c. feedback is applied, which stabilises the d.c. operating point of the output at around half supply voltage over a wide range of supply voltages without the need for adjustment potentiometers.





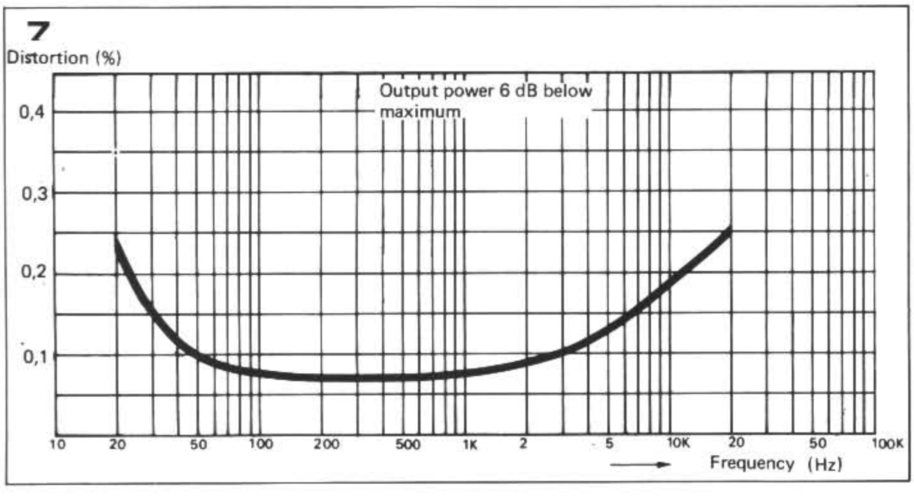


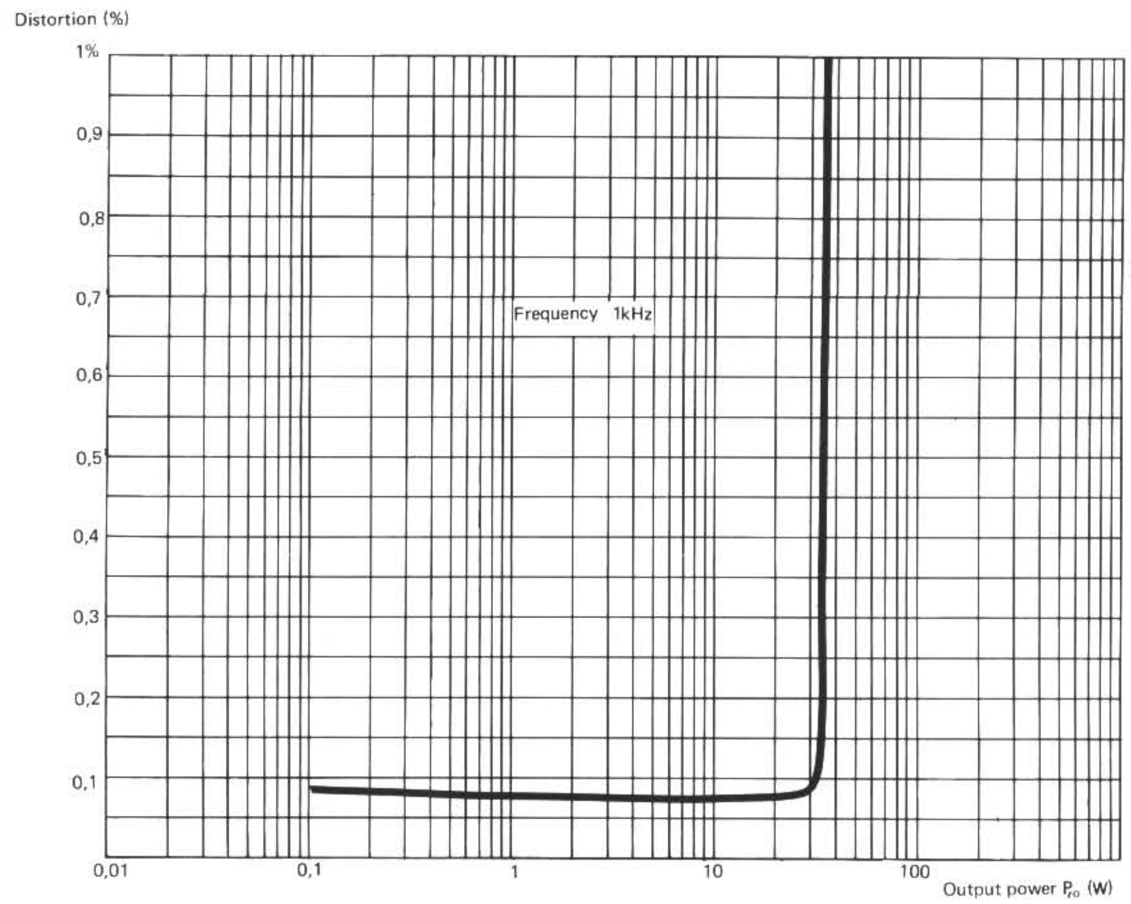
Figure 5. Maximum output power versus frequency.

Figure 6. Frequency response.

Figure 7. Distortion versus frequency for output power 6 dB below maximum.

Figure 8. Distortion versus output power.

8



The a.c. gain of the amplifier is, of course, given by

$$A_V = \frac{V_{out}}{V_{in}} = \frac{R_{10} + R_5}{R_5}.$$

It is worth noting the effect of the combination R7, C5 on the operation of the amplifier. Some amplifiers, when used with an unstabilised supply, display ripple on the peaks of the waveform when driven to clipping. This is eliminated by R7 and C5 as follows. When the amplifier is being driven, current flows through R7 and the voltage on C5 is always below the ripple 'troughs' on the supply. The drive voltage available from T3 is limited to the voltage on C5 and the output of the amplifier can never swing into the ripple region of the supply voltage. R7 also limits the current through T3 in the event of an overload.

Overload protection

The protection circuit is designed to prevent excessive current peaks from occurring during signal overloads or short-circuiting of the output. The protection circuit consists of transistors T5 and T6. Their base bias is set such that under normal operating conditions the voltage across R20 and R21 is insufficient to turn them on. In the event of excessive output current flowing in R20 or R21, due to a signal overload or a short-circuited output, the voltage across these resistors is sufficient to cause T5 or T6 to conduct. This reduces the drive voltage to the output stage and therefore limits the output current, thus protecting the amplifier.

Power supply

A stabilised power supply is unnecessary with the Edwin amplifier, as its performance will not be significantly improved. A simple unregulated supply is quite adequate and two suitable circuits are given in figure 3. Figure 3a shows a supply using a normal full-wave bridge rectifier, whilst figure 3b shows a full-wave rectifier with a centre-tapped transformer.

The component values and specification for supplies suitable for 20, 35 and 40 W versions of the amplifier are given in table 1. Of course any suitable transformer may be used, there is no need to adhere to the exact voltages specified. Figure 4 gives the output power available versus transformer secondary voltage. The only points to watch are that the current rating of the transformer is adequate for the required output power, that the voltage rating of the smoothing capacitor is sufficient and that the RMS secondary voltage of the transformer does not exceed 33 V on load, otherwise the voltage rating of the transistors may be exceeded.

Over the range of supply voltages given in figure 4 nothing need be changed in the amplifier as the operating point is self-adjusting.

Performance figures

The performance figures, as measured on the 35 W prototype of the amplifier are summarised in table II and displayed graphically in figures 5, 6, 7, and 8. As can be seen they are quite exceptional. Among the outstanding features are the large power bandwidth, good signal to noise ratio, immunity to transients, low distortion and absolute stability, even with large capacitive loads.

Figure 9 shows the printed circuit board and component layout of the amplifier.

Table I

$P_{o\ max}$ (W) (R_L = 4 Ohm)	V_{tr} RMS	$I_{tr\ max}$ (A) figure 3b		figure 3a	C1			Power supply no-load voltage (V)
			Mono		µF		working voltage	
		Mono	Stereo	Stereo	Mono	Stereo	(V)	
42	33	1,1	2,2	4,5	2500	5000	60	46,5
35	30	1	2	4			50	42,5
21	24	0,8	1,5	3			40	34

9

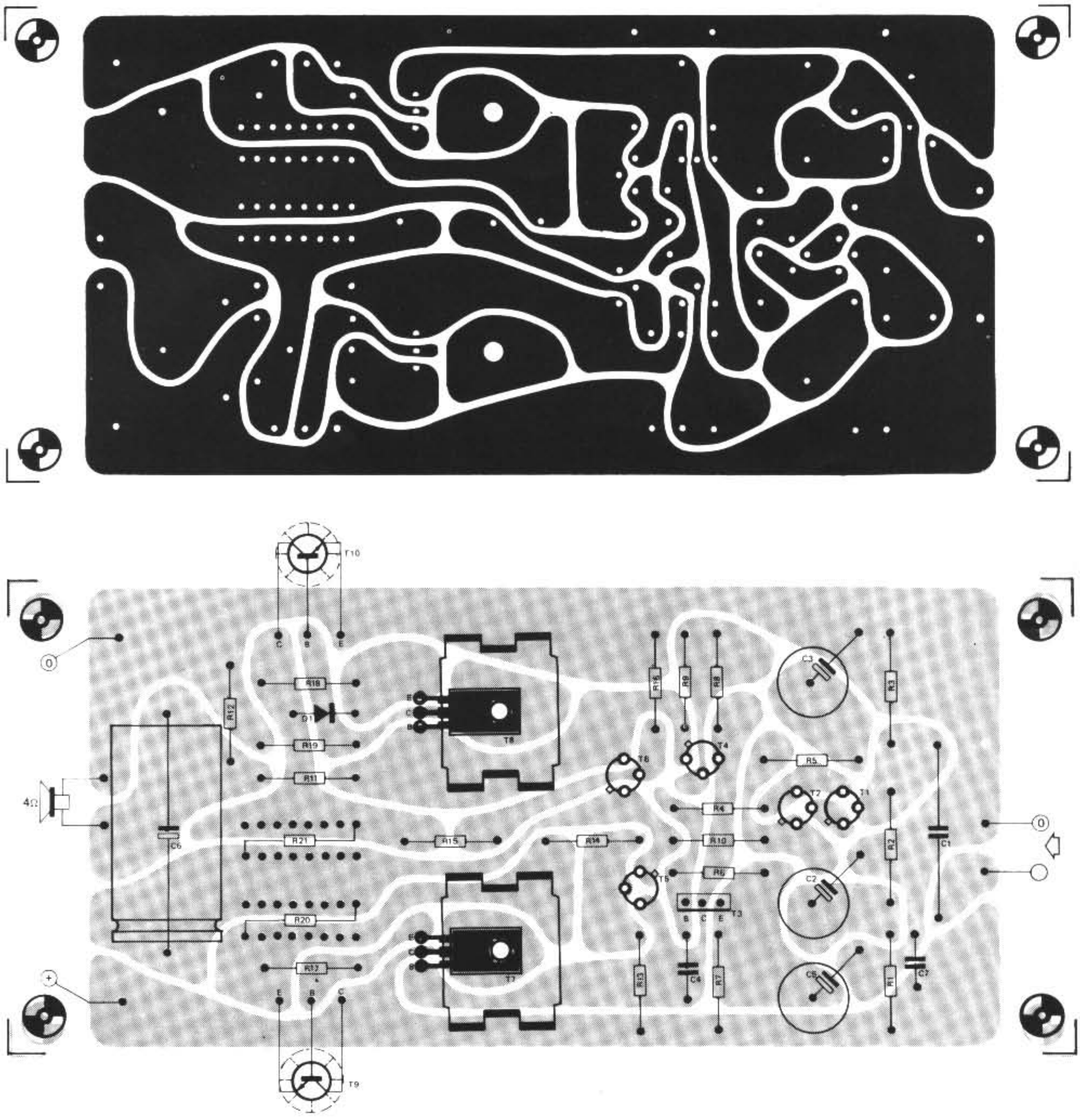


Figure 9. Printed circuit board and component layout.

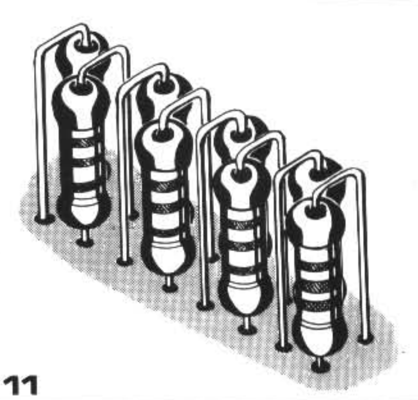
Figure 10. Heatsink details for the driver and output transistors.

Components list for figures 2 and 9

Resistors:
R1 = 10 k, ¼ W
R2 = 82 k, ¼ W
R3 = 100 k, ¼ W
R4 = 6k8, ¼ W
R5,R14,R15 = 100, ¼ W
R6,R8 = 680, ¼ W
R7,R12 = 220, ¼ W
R9 = 330, ¼ W
R10 = 1 k, ¼ W
R11 = 1k5, ¼ W
R13,R16 = 8k2, ¼ W
R17,R18,R19 = 10, ¼ W
R20,R21 = 0.12, 2 W

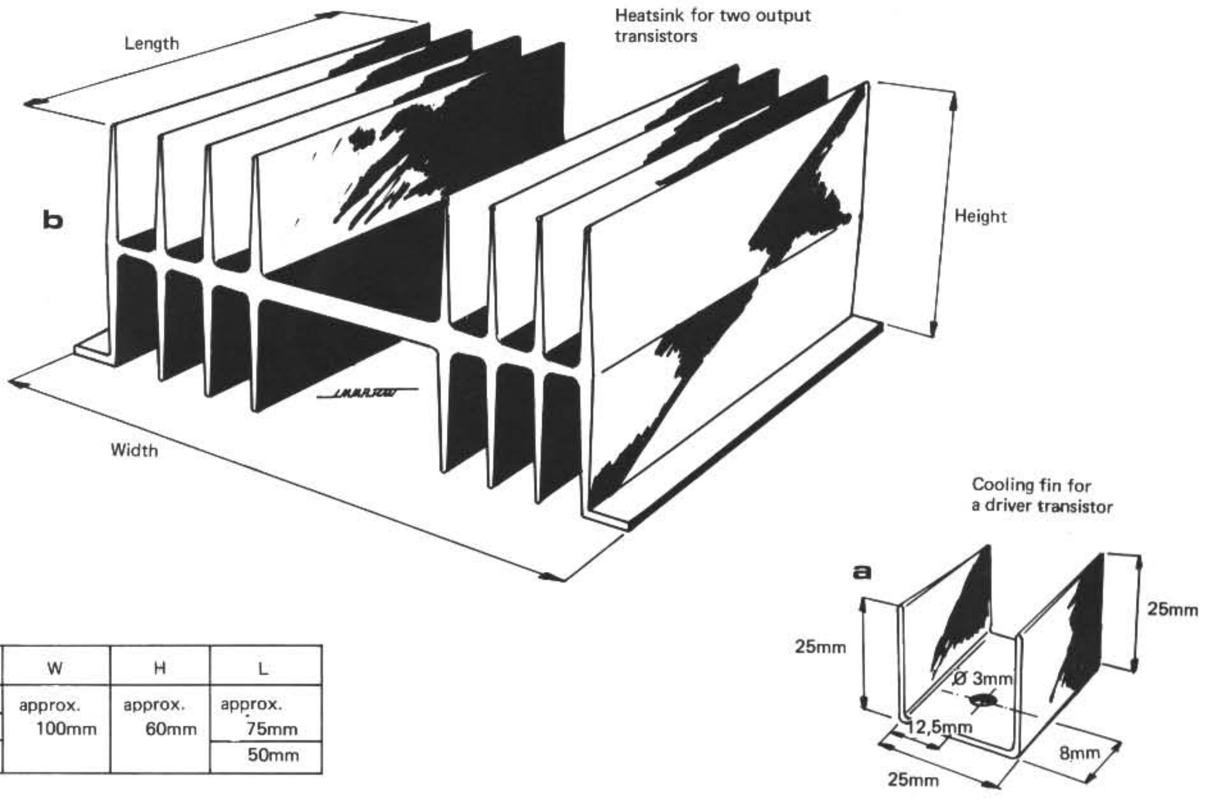
Capacitors:
C1 = 1 μ
C2 = 100 μ, 50 V
C3 = 100 μ, 25 V
C4 = 10 p ceramic
C5 = 250 μ, 50 V
C6 = 2500 μ, 50 V
C7 = 3n3

Semiconductors:
T1,T2 = BC 107, BC 171
T4,T5 = BC 108, BC 148
T3,T8 = BD 138
T6 = BC 178, BC 158
T7 = BD 137
T9,T10 = 2N3055, BD 130
D1 = BY 127



11

10


b
Length
Heatsink for two output transistors
Height
Width
Cooling fin for a driver transistor
a
25mm
25mm
Ø 3mm
12,5mm
8mm
25mm

P_o max.	W	H	L
42Watt	approx.	approx.	approx.
35Watt	100mm	60mm	75mm
21Watt			50mm

The driver transistors are mounted on the board, with a cooling fin as detailed in figure 10a. The output transistors are mounted on a separate extruded aluminium heatsink, details of which are given in figure 10b and the associated table. Most manufacturers of heatsinks will have something similar to this in their range.

If resistors R20 and R21 are not readily obtainable they may be wound from suitable resistance wire. Alternatively wire eight 1 Ω 0.25 W resistors in parallel, there is plenty of space on the board to mount them vertically (figure 11).

Concluding remarks

Whilst the Edwin amplifier meets an exacting specification this is no reason to recommend its construction by the Hi-Fi enthusiast. There are many other designs with similar performance. What makes the amplifier eminently suitable for the amateur is its problem-free construction and virtual (electrical) indestructibility. ◼

Table II

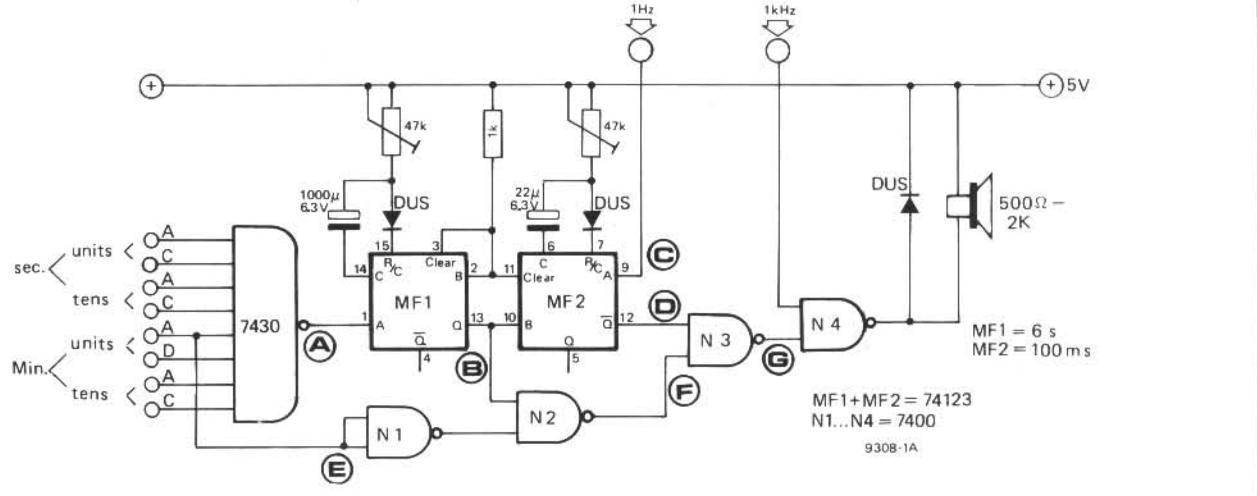
Performance figures of 35 W version		
Maximum output power	35 W (4 Ω); 20 W (8 Ω) 45 W (4 Ω); 27 W (8 Ω)	f = 1 kHz, THD = 1 % THD = 10%
Efficiency	> 60%	f = 1 kHz; P_o = 35 W
Load impedance	0 ... ∞ (Maximum power into 4 Ω)	
Overload protection	Proof against long duration short-circuit	
Maximum capacitive load	> 100 μF (!)	
Sensitivity	≈ 1 V RMS	f = 1 kHz, P_o = 35 W
Input impedance	≈ 45 kΩ	
Distortion	 0,1% 0,2% 0,3%	P_o = 0 ... 30 W f = 1 kHz f = 30 Hz f = 10 kHz
Frequency response	25 Hz ... 1,2 MHz (–3 dB) 40 Hz ... 1,0 MHz (–1 dB)	V_{in} = 245 mV
Power bandwidth	> 100 kHz (–3 dB)	
Noise rejection	73 dB 93 dB	input open-circuit input short-circuit
Signal to noise ratio	95 dB > 105 dB	input open-circuit input short-circuit
Feedback factor	≈ 36 dB	
Stability	unconditional	

time signal simulator

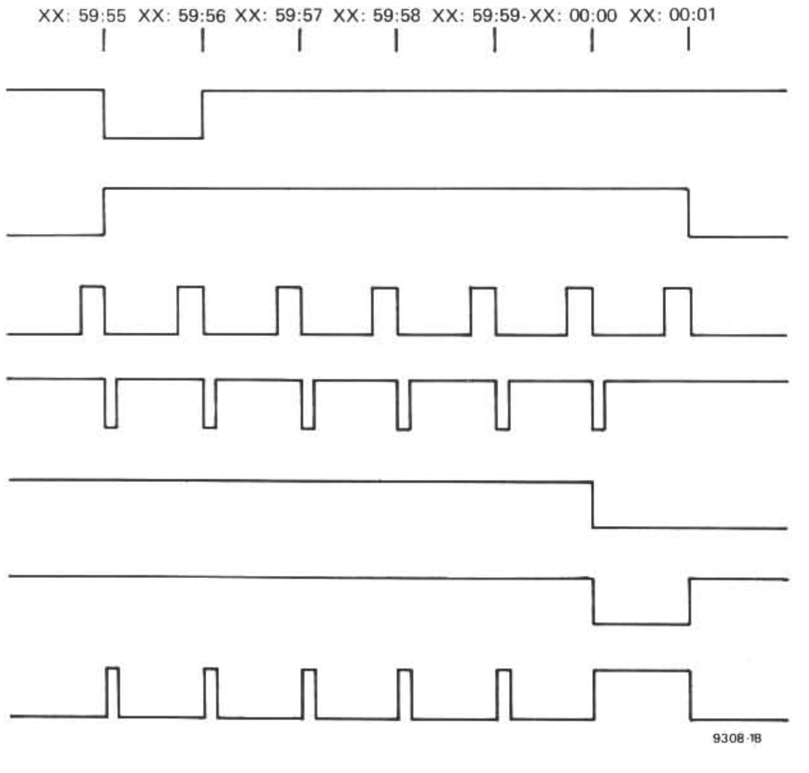
This circuit generates a 'six pips' signal indicating the exact hour.
At the instant the first 'pip' is to start, an eight-input NAND gate, which receives BCD-coded minute and second marks from a TTL clock, transmits a negative-going edge to MF1 (at A). Each digit requires not more than two inputs, the logic '1' level only being used for decoding. The code shown in the diagram corresponds to the moment 59'55''. The period of MF1 monostable is about 6 seconds. During this period monostable MF2 is triggered by a 1 Hz signal at (C), as shown in the pulse diagram, its B input being logic '1' (B). The MF2 monostable period has been set to about 100 millisec, which permits MF2 to be triggered every second. The result is a signal at (D).

Until the turn of the hour, the minute-unit mark remains logic '1' (E). N1 inverts this level, causing the signal at (F) also to be '1'.
At the instant 00'00'', N2 by-passes MF2. This means that MF2 only determines the length of the first five 'pips'. The length of the sixth 'pip' is determined by the remainder of the MF1 period (G). The new hour is, thus, marked by a 'pip' of a length of about 1 second.
The tone itself appears at the input of N4. If the clock is crystal controlled it may be possible to derive a frequency of around 1 kHz from the divider circuitry in the clock. Otherwise a simple 1 kHz multivibrator may be used.

1a



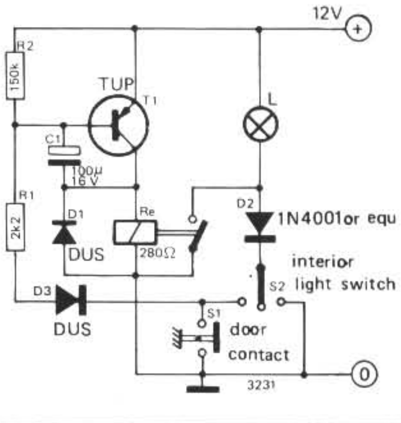
1b



afterburner

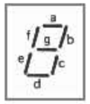
W. Ferdinand

When starting a car journey after dark it is useful to have a device which will keep the interior lighting on for a while after the doors have been closed, and so make it easier for the occupants to fasten safety belts and insert the ignition key. This can be done with the simple time-switch circuit shown.



Manufacturer	Type number	Colour	Pin Function														Performance Data					Maximum Ratings				Dimensions			h
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	λp	I_v	V_{fs}	V_{fd}	$@I_f$	V_{rs}	V_{rd}	I_{av}	P_{tot}	W	H	D	
Boss	BIM-72R	Red	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	697	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
Boss	BIM-52G	Green	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	560	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
Boss	BIM-82Y	Yellow	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	580	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
Dialco	745-0006	Red	a	f	A	np	np	L	e	d	A	c	g	np	b	A	650	—	3.2	1.6	20	6	3	30	380	10	19	3.0	6.9
EEP	EP1	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	1.0	2.1	2.1	15	5.5	5.5	40	750	10	19	3.2	8.5
EEP	EP21	Red	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	697	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
EEP	EP21G	Green	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	560	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
EEP	EP21Y	Yellow	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	580	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
EEP	EP27	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	0.30	2.2	2.2	20	3	3	40	750	10	19	3.2	8.5
EEP	EP28	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	0.60	2.2	2.2	20	3	3	40	750	10	19	3.2	8.5
Hewlett-Packard	5082-7730	Red	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	655	0.25	1.6	1.6	20	6	6	25	400	10	19	4.6	7.6
Hewlett-Packard	5082-7731	Red	a	f	A	np	np	nc	e	d	R	c	g	np	b	A	655	0.25	1.6	1.6	20	6	6	25	400	10	19	4.6	7.6
Hewlett-Packard	5082-7750	Red	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	655	0.25	1.6	1.6	20	6	6	25	400	13	19	6.4	11.0
Hewlett-Packard	5082-7751	Red	a	f	A	np	np	nc	e	d	R	c	g	np	b	A	655	0.25	1.6	1.6	20	6	6	25	400	13	19	6.4	11.0
Litronix	DL1A	Red	a	f	A	nc	nc	L	e	d	A	c	g	nc	b	A	630	—	3.4	1.6	20	6	3	30	750	10	19	3.0	6.9
Litronix	DL10	Red	a	f	A	nc	nc	L	e	d	A	c	g	nc	b	A	630	—	3.4	1.6	20	6	3	30	750	10	19	3.0	6.9
Litronix	DL10A	Red	a	f	A	nc	nc	L	e	d	A	c	g	nc	b	A	630	—	3.4	1.6	20	6	3	25	650	10	19	3.0	6.9
Litronix	DL707	Red	a	f	A	nc	nc	L	e	d	A	c	g	nc	b	A	630	1.4	1.7	1.7	20	3	3	30	500	11	20	7.4	7.6
Litronix	DL707R	Red	a	f	A	nc	nc	R	e	d	A	c	g	nc	b	A	630	1.4	1.7	1.7	20	3	3	30	500	11	20	7.4	7.6
Monsanto	MAN1	Red	a	f	A	nc	nc	L	e	d	A	c	g	nc	b	A	630	—	3.4	1.6	20	6	3	30	750	10	19	3.0	6.9
Monsanto	MAN1A	Red	a	f	A	nc	nc	L	e	d	A	c	g	nc	b	A	630	—	3.4	1.6	20	6	3	30	750	10	19	3.0	6.9
Monsanto	MAN5	Green	a	f	A	np	np	L	e	d	A	c	g	np	b	A	565	0.23	2.5	2.5	20	3	3	40	960	11	20	5.8	6.9
Monsanto	MAN7	Red	a	f	A	np	np	L	e	d	A	c	g	np	b	A	630	0.2	2.0	2.0	20	5	5	30	960	11	20	5.8	6.9
Monsanto	MAN8	Yellow	a	f	A	np	np	L	e	d	A	c	g	np	b	A	589	0.25	2.5	2.5	20	6	3	40	960	11	20	5.8	6.9
Monsanto	MAN51	Green	a	f	A	np	np	R	e	d	A	c	g	np	b	A	565	0.32	2.5	2.5	20	3	3	30	700	10	20	5.0	7.6
Monsanto	MAN52	Green	a	f	A	np	np	L	e	d	A	c	g	np	b	A	565	0.32	2.5	2.5	20	3	3	30	700	10	20	5.0	7.6
Monsanto	MAN71	Red	a	f	A	np	np	R	e	d	A	c	g	np	b	A	650	0.30	1.6	1.6	20	5	5	30	700	10	20	5.0	7.6
Monsanto	MAN72	Red	a	f	A	np	np	L	e	d	A	c	g	np	b	A	650	0.30	1.6	1.6	20	5	5	30	700	10	20	5.0	7.6
Monsanto	MAN81	Yellow	a	f	A	np	np	R	e	d	A	c	g	np	b	A	590	0.34	2.5	2.5	20	3	3	30	700	10	20	5.0	7.6
Monsanto	MAN82	Yellow	a	f	A	np	np	L	e	d	A	c	g	np	b	A	590	0.34	2.5	2.5	20	3	3	30	700	10	20	5.0	7.6
Monsanto	MAN3610	Orange	a	f	A	np	np	R	e	d	A	c	g	np	b	A	630	1.2	2.0	2.0	10	3	3	20	400	10	20	5.0	7.6
Monsanto	MAN3620	Orange	a	f	A	np	np	L	e	d	A	c	g	np	b	A	630	1.2	2.0	2.0	10	3	3	20	400	10	20	5.0	7.6
Norbain	NOR1	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	1.0	2.1	2.1	15	5.5	5.5	40	750	10	19	3.1	8.4
Norbain	NDP1	Red	a	f	nc	nc	nc	nc	e	d	nc	c	g	nc	b	A	690	1.0	2.1	—	15	5.5	—	40	750	10	19	3.1	8.4
Norbain	NOR1R	Red	a	nc	f	g	nc	e	A	d	c	nc	nc	nc	R	b	690	1.0	2.1	2.1	15	5.5	5.5	40	750	10	19	3.1	8.4
Norbain	NOR1C	Red	a	f	j	nc	nc	L	e	d	nc	c	g	nc	b	A	690	1.0	2.1	2.1	15	5.5	5.5	40	750	10	19	3.1	8.4
Norbain	NOR7	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	0.3	2.2	2.2	20	3	3	40	750	10	19	3.1	8.4
Norbain	NOR8	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	0.6	2.2	2.2	20	3	3	40	750	10	19	3.1	8.4
Opcoa	SLA1	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	1.0	2.1	2.1	15	5.5	5.5	40	750	10	19	3.2	8.4
Opcoa	SLA7	Red	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	690	0.3	2.1	2.1	20	3	3	40	750	10	19	3.2	8.4
Opcoa	SLA11	Green	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	560	0.7	2.6	2.6	40	5.5	5.5	50	1480	10	19	3.2	8.4
Opcoa	SLA21	Yellow	a	f	nc	nc	nc	L	e	d	nc	c	g	nc	b	A	580	0.7	2.6	2.6	40	5.5	5.5	50	1480	10	19	3.2	8.4
Texas	TIL302	Red	a	f	A	np	np	L	e	d	A	c	g	np	b	A	650	0.28	3.4	1.6	20	6	3	30	800	10	19	3.0	6.5
Texas	TIL303	Red	a	A	f	g	np	e	A	d	c	R	np	np	A	b	650	0.28	3.4	1.6	20	6	3	30	800	10	19	3.0	6.5
Xeiton	XAN72	Red	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	697	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
Xeiton	XAN52	Green	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	560	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7
Xeiton	XAN82	Yellow	a	f	A	np	np	L	e	d	nc	c	g	np	b	A	580	0.25	1.9	1.9	10	5	5	25	400	10	19	4.6	7.7

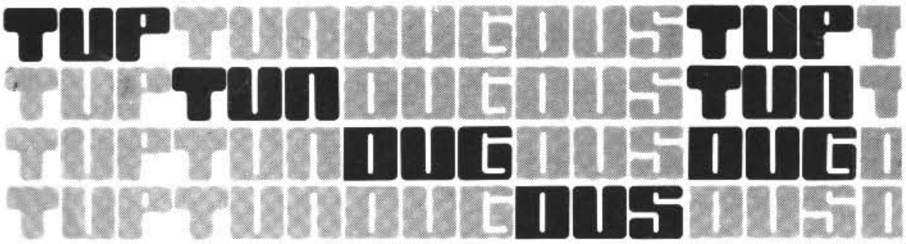
Pin connections and performance data for common-anode 7-segment LED displays.



Explanation of Symbols.

a-g	Segment cathodes.
L	Left-hand decimal point cathode.
R	Right-hand decimal point cathode.
j	Upper decimal point (colon) cathode.
A	Anode.
nc	No connection.
np	No pin.
λp	Peak emission wavelength (nanometres).
I_v	Luminous intensity (millicandelas) at specified forward current.
V_{fs}	Segment forward voltage at specified current (volts).
V_{fd}	Decimal point forward voltage drop at specified current (volts).
$@I_f$	Specified forward current (milliamps).
V_{rs}	Max. segment reverse voltage (volts).
V_{rd}	Max. decimal point reverse voltage (volts).
I_{av}	Max. continuous forward current per segment (milliamps).
P_{tot}	Max. total device dissipation (milliwatts).
W	Width (millimetres).
H	Height (millimetres).
D	Depth (millimetres).
h	Character height (millimetres).

All the parameters listed are measured at 25°C. Values are typical, except for maximum ratings which must not be exceeded.



Wherever possible in Elektor circuits, transistors and diodes are simply marked 'TUP' (Transistor, Universal PNP), 'TUN' (Transistor, Universal NPN), 'DUG' (Diode, Universal Germanium) or 'DUS' (Diode, Universal Silicon). This indicates that a large group of similar devices can be used, provided they meet the minimum specifications listed in tables 1a and 1b.

For further information, see the article 'TUP-TUN-DUG-DUS'.

	type	U_{ce_0} max	I_c max	h_{fe} min.	P_{tot} max	f_T min.
TUN	NPN	20 V	100 mA	100	100 mW	100 MHz
TUP	PNP	20 V	100 mA	100	100 mW	100 MHz

Table 1a. Minimum specifications for TUP and TUN.

Table 1b. Minimum specifications for DUS and DUG.

	type	U_R max	I_F max	I_R max	P_{tot} max	C_D max
DUS	Si	25 V	100 mA	1 μA	250 mW	5 pF
DUG	Ge	20 V	35 mA	100 μA	250 mW	10 pF

Table 2. Various transistor types that meet the TUN specifications.

TUN		
BC 107	BC 208	BC 384
BC 108	BC 209	BC 407
BC 109	BC 237	BC 408
BC 147	BC 238	BC 409
BC 148	BC 239	BC 413
BC 149	BC 317	BC 414
BC 171	BC 318	BC 547
BC 172	BC 319	BC 548
BC 173	BC 347	BC 549
BC 182	BC 348	BC 582
BC 183	BC 349	BC 583
BC 184	BC 382	BC 584
BC 207	BC 383	

The letters after the type number denote the current gain:
A: α' (β, h_{fe}) = 125-260
B: α' = 240-500
C: α' = 450-900.

Table 3. Various transistor types that meet the TUP specifications.

TUP		
BC 157	BC 253	BC 352
BC 158	BC 261	BC 415
BC 177	BC 262	BC 416
BC 178	BC 263	BC 417
BC 204	BC 307	BC 418
BC 205	BC 308	BC 419
BC 206	BC 309	BC 512
BC 212	BC 320	BC 513
BC 213	BC 321	BC 514
BC 214	BC 322	BC 557
BC 251	BC 350	BC 558
BC 252	BC 351	BC 559

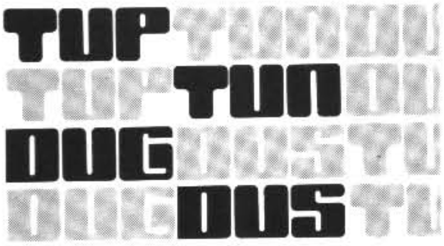


Table 4. Various diodes that meet the DUS or DUG specifications.

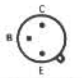
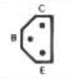
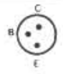
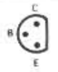
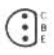
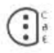
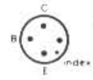
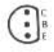
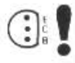
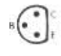
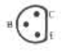
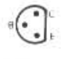
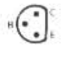
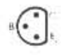
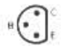
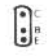
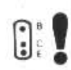
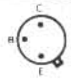
DUS		DUG
BA 127	BA 318	OA 85
BA 217	BAX13	OA 91
BA 218	BAY61	OA 95
BA 221	1N914	AA 116
BA 222	1N4148	
BA 317		

Table 5. Minimum specifications for the BC107, -108, -109 and BC177, -178, -179 families (according to the Pro-Electron standard). Note that the BC179 does not necessarily meet the TUP specification ($I_{c,max}$ = 50 mA).

	NPN	PNP
	BC 107 BC 108 BC 109	BC 177 BC 178 BC 179
V_{ce_0} max	45 V 20 V 20 V	45 V 25 V 20 V
V_{eb_0} max	6 V 5 V 5 V	5 V 5 V 5 V
I_c max	100 mA 100 mA 100 mA	100 mA 100 mA 50 mA
$P_{tot.}$ max	300 mW 300 mW 300 mW	300 mW 300 mW 300 mW
f_T min.	150 MHz 150 MHz 150 MHz	130 MHz 130 MHz 130 MHz
F max	10 dB 10 dB 4 dB	10 dB 10 dB 4 dB

The letters after the type number denote the current gain:
A: α' (β, h_{fe}) = 125-260
B: α' = 240-500
C: α' = 450-900.

Table 6. Various equivalents for the BC107, -108, . . . families. The data are those given by the Pro-Electron standard; individual manufacturers will sometimes give better specifications for their own products.

NPN	PNP	Case	Remarks
BC 107 BC 108 BC 109	BC 177 BC 178 BC 179		
BC 147 BC 148 BC 149	BC 157 BC 158 BC 159		P_{max} = 250 mW
BC 207 BC 208 BC 209	BC 204 BC 205 BC 206		
BC 237 BC 238 BC 239	BC 307 BC 308 BC 309		
BC 317 BC 318 BC 319	BC 320 BC 321 BC 322		I_{cmax} = 150 mA
BC 347 BC 348 BC 349	BC 350 BC 351 BC 352		
BC 407 BC 408 BC 409	BC 417 BC 418 BC 419		P_{max} = 250 mW
BC 547 BC 548 BC 549	BC 557 BC 558 BC 559		P_{max} = 500 mW
BC 167 BC 168 BC 169	BC 257 BC 258 BC 259		169/259 I_{cmax} = 50 mA
BC 171 BC 172 BC 173	BC 251 BC 252 BC 253		251 . . . 253 low noise
BC 182 BC 183 BC 184	BC 212 BC 213 BC 214		I_{cmax} = 200 mA
BC 582 BC 583 BC 584	BC 512 BC 513 BC 514		I_{cmax} = 200 mA
BC 414 BC 414 BC 414	BC 416 BC 416 BC 416		low noise
BC 413 BC 413	BC 415 BC 415		low noise
BC 382 BC 383 BC 384			
BC 437 BC 438 BC 439			P_{max} = 220 mW
BC 467 BC 468 BC 469			P_{max} = 220 mW
	BC 261 BC 262 BC 263		low noise

Type	PNP = P NPN = N	V_{CEO} (Volt) 0 = ≤ 20 00 = 25-40 000 = 45-60 0000 = 65-80 00000 = ≥ 85	$I_{c(max)}$ (mA) 0 = ≤ 50 00 = 55-100 000 = 105-400 0000 = 405-2 A 00000 = ≥ 2 A	P_{max} (mW) not cooled: 0 = ≤ 300 00 = 305-1000 cooled: 00☆ = 1-10 W 00☆☆ = 10-35 W 00☆☆☆ = ≥ 40 W	$h_{FE(min)}$ 0 = ≤ 20 00 = 25-50 000 = 55-120 0000 = ≥ 125	case nr.	comments
TUN	N	0	00	0	000		
TUP	P	0	00	0	000		
AC126	P	0	00	00	0000	2	
AF239	P	0	0	0	0	1	grounded base: f f_T = 700 MHz
BC107	N	000	00	0	000	2	
BC108	N	0	00	0	000	2	
BC109	N	0	00	0	0000	2	low noise
BC140	N	00	0000	00☆	00	2	
BC141	N	000	0000	00☆	00	2	
BC160	P	00	0000	00☆	00	2	
BC161	P	000	0000	00☆	00	2	
BC182	N	000	000	0	0000	2	
BC212	P	000	000	0	000	2	
BC546	N	0000	00	00	0000	2	
BC556	P	0000	00	00	000	2	
BD106	N	00	00000	00☆☆	00	7	
BD130	N	000	00000	00☆☆☆	0	7	
BD132	P	000	00000	00☆☆	00	9	
BD137	N	000	0000	00☆	00	9	
BD138	P	000	0000	00☆	00	9	
BD139	N	0000	0000	00☆	00	9	
BD140	P	0000	0000	00☆	00	9	
BDY20	N	000	00000	00☆☆☆	0	7	
BF180	N	0	0	0	0	1	grounded base: f_T = 675 MHz
BF185	N	0	0	0	00	12	grounded base: f_T = 220 MHz
BF194	N	0	0	0	000	10	grounded emitter: f_T = 260 MHz
BF195	N	0	0	0	000	10	grounded emitter: f_T = 200 MHz
BF199	N	00	0	00	000	11	grounded emitter: f_T = 550 MHz
BF200	N	0	0	0	00	1	grounded base: f_T = 240 MHz
BF254	N	00	0	0	000	11	grounded emitter: f_T = 260 MHz
BF257	P	00000	00	00	00	2	grounded emitter: f_T = 90 MHz
BF494	N	0	0	0	000	6	grounded emitter: f_T = 260 MHz
BFX34	N	000	00000	00	00	2	f_T = 70 MHz
BFX89	N	0	0	0	00	1	grounded emitter: f_T = 1000 MHz
BFY90	N	0	0	0	00	1	grounded emitter: f_T = 1000 MHz
BSX19	N	0	0000	0	000	2	
BSX20	N	0	0000	0	000	2	
BSX61	N	000	0000	00	000	2	
HEP51	P	00	0000	00	000	1	f_T = 150 MHz
HEP53	N	00	0000	00	000	1	f_T = 200 MHz
HEP56	N	0	00	00	000	5	f_T = 750 MHz
MJE171	P	000	00000	00☆☆	00	9	
MJE180	N	00	00000	00☆☆	00	9	
MJE181	N	000	00000	00☆☆	00	9	
MJE340	N	00000	0000	00☆☆	00	9	
MPS A05	N	000	0000	00	00	13	
MPS A06	N	0000	0000	00	00	13	
MPS A09	N	0000	0	00	000	13	
MPS A10	N	00	00	00	00	13	
MPS A13	N	00	000	00	0000	13	
MPS A16	N	00	00	00	0000	13	
MPS A17	N	00	00	00	0000	13	
MPS A18	N	000	000	00	0000	13	
MPS A55	P	000	0000	0	00	13	
MPS A56	P	0000	0000	0	00	13	
MPS U01	N	00	00000	00☆	00	14	
MPS U05	N	000	00000	00☆	00	14	
MPS U56	P	0000	00000	00☆	00	14	
MPS2926	N	0	00	00	00	13	f_T = 300 MHz
MPS3394	N	00	00	00	000	13	
MPS3702	P	00	000	00	000	13	f_T = 100 MHz
MPS3706	N	0	0000	00	00	13	
MPS6514	N	00	00	0	0000	13	f_T = 480 MHz
TIP29	N	00	0000	00☆☆	0	3	
TIP30	P	00	0000	00☆☆	0	3	
TIP31	N	00	00000	00☆☆☆	0	3	
TIP32	P	00	00000	00☆☆☆	0	3	
TIP140	N	000	00000	00☆☆☆	0000	7	Darlington
TIP142	N	00000	00000	00☆☆☆	0000	7	Darlington
TIP2955	P	000	00000	00☆☆☆	0	3	
TIP3055	N	000	00000	00☆☆☆	0	3	
TIP5530	P	000	00000	00☆☆☆	0	3	
2N696	N	000	0000	00	0	2	
2N706	N	0	0	0	0	2	
2N914	N	0	0000	00	00	2	
2N1613	N	000	0000	00	00	2	
2N1711	N	000	0000	00	000	2	
2N1983	N	00	0000	00	000	2	
2N1984	N	00	0000	00		2	
2N2219	N	00	0000	00	00	2	
2N2222	N	00	0000	00	00	2	
2N2925	N	00	00	0	0000	13	
2N2955	P	00	00	0	0	2	≠ MJE2955, TIP2955!
2N3054	N	000	00000	00☆☆☆	00	7	
2N3055	N	000	00000	00☆☆☆	0	7	
2N3553	N	00	0000	00☆	0	2	f_T = 500 MHz
2N3568	N	000	0000	0	000	13	
2N3638	P	00	0000	0	000	13	
2N3702	P	00	000	00	000	13	
2N3866	N	00	000	00☆	0	2	f_T = 700 MHz
2N3904	N	00	000	0	00	13	
2N3905	P	00	000	00	000	13	
2N3906	P	00	000	00	000	13	
2N3907	N	000	0	0	000	13	
2N4123	N	00	000	0	00	13	
2N4124	N	00	000	0	000	13	
2N4126	P	00	000	0	000	13	
2N4401	N	00	0000	00	0	13	
2N4410	N	0000	000	00	000	13	
2N4427	N	0	000	00☆	0	2	f_T = 700 MHz
2N5183	N	0	0000	00	000	2	

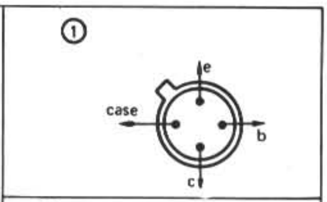
The letters after the type number denote the current gain:

A: α' (β, h_{fe}) = 125-260

B: α' = 240-500

C: α' = 450-900.

①



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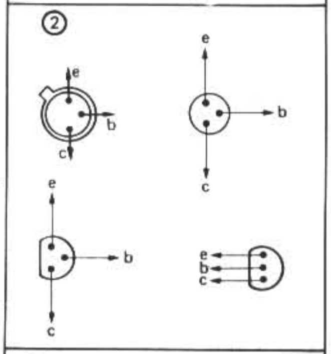

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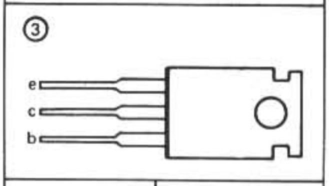

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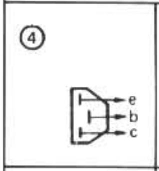

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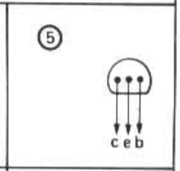

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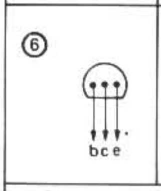

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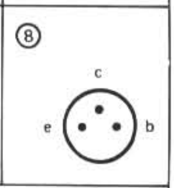

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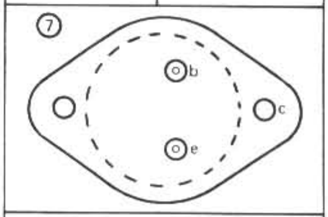

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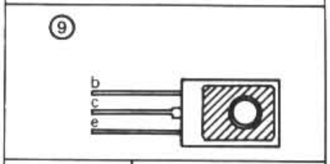

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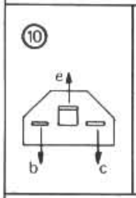

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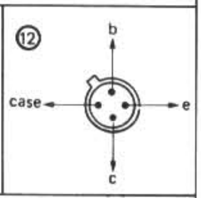

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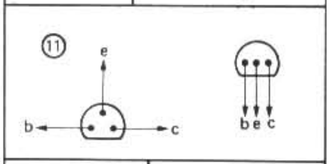

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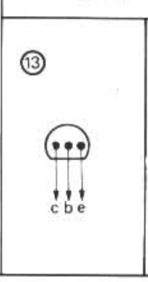

⑭